This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

BRANNER
GEOLOGICAL LIBRARY

STANFORD UNIVERSITY LIBRARIES

Water-Supply and Irrigation Paper No. 84 Series P, Hydrographic Progress Reports, 22

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

REPORT

OF

PROGRESS OF STREAM MEASUREMENTS

FOR

THE CALENDAR YEAR 1902

BY

F. H. NEWELL

PART III.—WESTERN MISSISSIPPI AND WESTERN GULF DRAINAGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

BRANNER
GEOLOGICAL LIBRARY

STANFORD UNIVERSITY LIBRARIES

[illegible]

[illegible]

UNITED STATES [illegible]

REPORT

PROGRESS OF STREAM MEASUREMENTS

THE CALENDAR YEAR [illegible]

F. H. NEWELL

91

659123

CONTENTS.

	Page.
Letter of transmittal	7
Introduction	9
Acknowledgments	12
Upper Mississippi River drainage	13
Missouri River drainage basin	13
Marais des Cygnes River at Ottawa, Kans	14
Big Sioux River near Watertown, S. Dak	15
Niobrara River at Niobrara, Nebr	16
Niobrara River at Valentine, Nebr	18
Clear Creek at Buffalo, Wyo	20
Piney Creek at Kearney, Wyo	21
Shoshone River at Cody, Wyo	21
Bighorn River near Thermopolis, Wyo	23
Yellowstone River near Livingston, Mont	24
Milk River at Malta, Mont	26
Milk River at Havre, Mont	28
Musselshell River at Shawmut, Mont	31
Marias River near Shelby, Mont	32
Two Medicine Creek at Midvale, Mont	34
Missouri River at Cascade, Mont	35
Missouri River at Townsend, Mont	36
Gallatin River at Logan, Mont	38
West Gallatin River near Salesville, Mont	40
Middle Creek near Bozeman, Mont	43
Madison River near Redbluff, Mont	46
Jefferson River at Sappington, Mont	47
Miscellaneous measurements in Missouri River drainage basin	49
Platte River drainage basin	50
Elkhorn River near Arlington, Nebr	51
Elkhorn River near Norfolk, Nebr	53
Loup River at Columbus, Nebr	55
Platte River near Columbus, Nebr	57
Platte River near Lexington, Nebr	59
North Platte River at North Platte, Nebr	62
North Platte River at Bridgeport, Nebr	64
North Platte River at Mitchell, Nebr	66
North Platte River at Guernsey, Wyo	68
Little Laramie River at May's ranch near Hatton, Wyo	70
Sweetwater River at Devils Gate near Splitrock, Wyo	72
South Platte River at Bigspring, Nebr	72
South Platte River at Julesburg, Colo	73
Middle Crow Creek near Hecla, Wyo	75
South Platte River at Kersey, Colo	77

Western Mississippi River drainage—Continued.
Platte River drainage basin—Continued. Page.
Big Thompson Creek near Arkins, Colo 79
St. Vrain Creek at Lyons, Colo 81
Clear Creek at Forkscreek, Colo 84
South Platte River at Denver, Colo 86
Bear Creek near Morrison, Colo 89
South Platte River at South Platte, Colo 89
Miscellaneous measurements in the Platte River drainage basin 92
Kansas River drainage basin 95
Kansas or Kaw River at Lecompton, Kans 95
Blue River near Manhattan, Kans 97
Republican River at Junction, Kans 100
Republican River and the mill race near Superior, Nebr 102
Solomon River at Niles, Kans 105
Saline River near Salina, Kans 108
Smoky Hill River at Ellsworth, Kans 110
Miscellaneous measurements in the Kansas River drainage basin 112
Arkansas River drainage basin 113
Canadian River (North Fork) near Elreno, Okla 114
Neosho River at Iola, Kans 115
Verdigris River near Liberty, Kans 116
Walnut River at Arkansas City, Kans 119
Arkansas River at Arkansas City, Kans 119
Arkansas River at Hutchinson, Kans 120
Arkansas River at Dodge, Kans 123
Arkansas River at Syracuse, Kans 123
Arkansas River at Barton, Colo 125
Arkansas River near Rockyford, Colo 126
Arkansas River near Nepesta, Colo 128
Arkansas River at Pueblo, Colo 130
Arkansas River near Canyon, Colo 133
Arkansas River at Salida, Colo 136
Miscellaneous measurements in the Arkansas River drainage basin 138
Red River drainage basin 139
Washita River at Anadarko, Okla 139
Miscellaneous measurements in the Red River drainage basin 140
Western Gulf drainage 140
Sabine River drainage basin 140
Miscellaneous measurements in Sabine drainage basin 141
Neches River drainage basin 141
Miscellaneous measurements in Neches drainage basin 142
Trinity River drainage basin 142
Trinity River at Riverside, Tex 142
Brazos River drainage basin 143
Brazos River at Waco, Tex 143
Brazos River at Richmond, Tex 147
Little River and its tributaries 147
Colorado River (of Texas) drainage basin 148
Colorado River at Columbus, Tex 149
Colorado River at Austin, Tex 149
Miscellaneous measurements on Colorado River 152
Barton Springs, near Austin, Tex 152
Llano River, Tex 153
San Saba River, Tex 154

estern Gulf drainage—Continued. Page.
Guadalupe River drainage basin 156
Guadalupe River near Cuero, Tex 156
Miscellaneous measurements in Guadalupe River drainage basin 157
Rio Grande drainage basin 157
Rio Grande at Eagle Pass, Tex 158
Las Moras Creek, Tex 161
San Felipe Creek, Tex 161
Rio Grande below mouth of Devils River, Tex 161
Devils River at Devilsriver, Tex 164
Pecos River near Moorhead, Tex 166
Pecos River, Margueretta flume, and West Valley ditch, near Pecos, Tex 168
Rio Grande at Langtry, Tex 172
Rio Grande below Presidio, Tex 175
Rio Grande above Presidio, Tex 177
Rio Grande near Fort Hancock, Tex 179
Rio Grande near El Paso, Tex 181
Rio Grande near San Marcial, N. Mex 183
Rio Grande at Water Tank, near Rio Grande or Buckman, N. Mex 186
Rio Grande at Embudo, N. Mex 189
Rio Grande near Cenicero, Colo 192
Rio Grande near Del Norte, Colo 194

ILLUSTRATIONS.

		Page.
FIG. 1.	Location of river stations and principal irrigation projects in western half of United States, 1902–3	10
2.	Location of river stations in eastern half of United States, 1902–3	11

LETTER OF TRANSMITTAL.

DEPARMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 29, 1903.

SIR: I have the honor to transmit herewith Water-Supply Paper No. 84, which is Part III of the Report of Progress of Stream Measurements for 1902. This paper contains the data which has been received during 1902 from that portion of the territory west of the Mississippi River which drains either into the Mississippi River or the western Gulf of Mexico. This paper will be followed by Water-Supply Paper No. 85, which will contain the data from the remainder of the Western States, and will also complete the Progress Report of Stream Measurements for 1902.

These papers contain, for the various gaging stations, the original data as collected and the results obtained from the discussion of these data, also such other information as is of interest in hydrographic studies.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PROGRESS REPORT OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1902.

PART III.

By F. H. NEWELL.

INTRODUCTION.

This paper contains the data collected in the territory which drains from the West either into the Gulf of Mexico or the Mississippi River, and for convenience in arrangement the material has been grouped under these two headings. This paper with Water-Supply Paper No. 85 make up the Progress Report of Stream Measurements for the territory west of the Mississippi River. The report for the territory east of the Mississippi River is contained in Water-Supply Papers Nos. 82 and 83. The material in each of these papers consists of both the original data as collected at the various river stations and the results obtained from the discussion of these data; also brief descriptions and facts regarding such other subjects as are allied to hydrographic studies.

For convenience in arrangement the data under the two main parts of this paper have been grouped by drainage areas and these have been arranged geographically from North to South.

In collecting hydrographic data the Geological Survey has received the hearty cooperation of various individuals, corporations, and States, as mentioned hereafter. This cooperation has made possible the publication of many valuable records which could not otherwise have been obtained.

A brief historical sketch of the stream measurements made by the Geological Survey is published on pages 11 to 15 of Water-Supply Paper No. 75.

On figs. 1 and 2 the full dots show the relative location of the stations at which the U. S. Geological Survey is collecting hydrographic data. The section west of the shaded line comprises those States which are

covered by the national irrigation act of June 17, 1902 (Stat. L., vol. 32, pp. 388–390), and the cross-lined areas show the location of the irrigation projects which are now under investigation.

The results of the stream measurements made during the past years

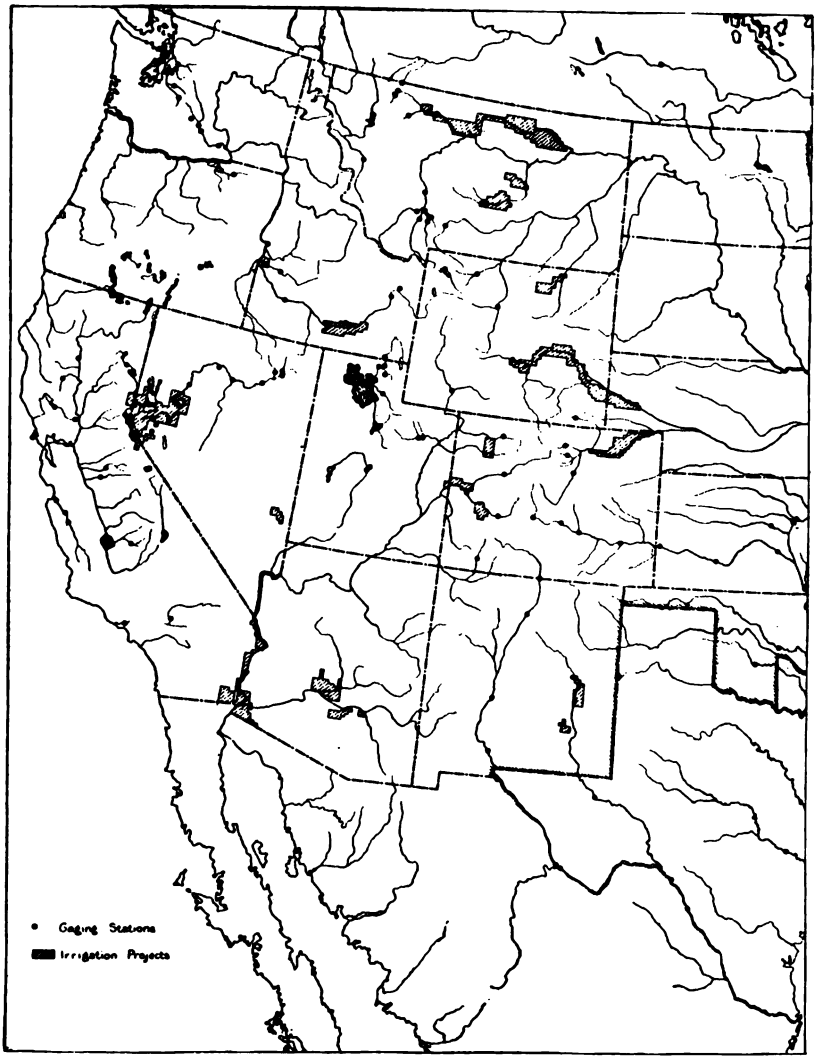


FIG. 1.—Location of river stations and principal irrigation projects in western half of United States, 1902–3.

by the U. S. Geological Survey can be found in the following publications, which may be consulted at the public libraries in most cities:

1893. Bulletin No. 131.
1894. Bulletin No. 131.
1895. Bulletin No. 140.

Water-Supply Paper No. 11; Part IV of the Eighteenth Annual Report.
Water-Supply Papers Nos. 15 and 16; Part IV of the Nineteenth Annual

Water-Supply Papers Nos. 27 and 28; Part IV of the Twentieth Annual

FIG. 2.—Location of river stations in eastern half of United States, 1902-3.

Water-Supply Papers Nos. 35 to 39, inclusive; Part IV of the Twenty-first Report.

Water-Supply Papers Nos. 47 to 52, inclusive; Part IV of the Twenty-Annual Report.

Water-Supply Papers Nos. 65, 66, and 75.

Water-Supply Papers Nos. 82 and 85, inclusive.

ACKNOWLEDGMENTS.

Most of the measurements presented in this paper have been obtained through local hydrographers and engineers. Acknowledgment is due to each of these persons, and thanks are extended to other persons and corporations who have assisted local hydrographers or who have cooperated in any way, either by furnishing records or by assisting in transportation.

The following list, arranged alphabetically by States, gives the names of the resident hydrographers and others who have assisted in furnishing and preparing the data contained in this report:

Colorado.—Resident hydrographer, A. L. Fellows, assisted by M. C. Hinderlider. Acknowledgments are also due to the following individuals and corporations for assistance rendered and data furnished: Hon. A. J. McCune, State engineer of Colorado; Hon. J. J. Armstrong, E. R. Chew, and A. F. Reeves, superintendents of irrigation; L. H. Dickson and T. J. Burrows, water commissioners; also to other water commissioners who have given assistance from time to time.

Transportation has been furnished by the Denver and Rio Grande, Atchison, Topeka and Santa Fe, Colorado and Southern, Union Pacific, and Rio Grande Southern railroads.

Special assistance was rendered by the officers of the Arkansas Valley Beet and Irrigated Land Company, at Lamar, and C. A. Jones, at Forks Creek.

Kansas.—Resident hydrographer, W. G. Russell. Acknowledgments are also due to the Chicago, Rock Island and Pacific; Missouri, Kansas and Texas; Atchison, Topeka and Santa Fe, and Union Pacific railways for transportation furnished resident hydrographer in Kansas, Oklahoma, and Indian Territory.

Montana.—Resident hydrographer, J. S. Baker, assisted by H. B. Waters. Acknowledgments are also due to Arthur P. Stover, who furnished the results of a number of measurements on the West Gallatin River, near Salesville, Mont., and on Middle Creek, near Bozeman, Mont.

Nebraska.—Resident hydrographer, J. C. Stevens. Acknowledgments are also due to the following individuals and corporations for assistance rendered and data furnished:

Adna Dobson, C. E., State engineer, secretary of the State board of irrigation; B. E. Forbes, assistant secretary State board of irrigation; H. O. Smith, Lexington, Nebr., under secretary State board of irrigation; Robert H. Willis, C. E., Bridgeport, Nebr., under assistant State board of irrigation. The Burlington and Missouri River, and Fremont, Elkhorn and Missouri Valley Railroad Companies have also rendered valuable assistance.

New Mexico.—Acknowledgments are due to W. W. Follett, consulting engineer International (Water) Boundary Commission, for the data at stations upon the Rio Grande River both in New Mexico and Texas.

Oklahoma.—Resident hydrographer, W. G. Russell.

South Dakota.—Resident hydrographer, J. C. Stevens, assisted by Prof. A. B. Crane, Brookings, S. Dak.

Texas.—Resident hydrographer, Thomas U. Taylor.

Wyoming.—Resident hydrographer, A. J. Parshall. Acknowledgments are also due to the following individuals and corporations for assistance rendered and data furnished:

To H. G. Burt, president of Union Pacific Railroad Company; to G. W. Holdrege, general manager Burlington and Missouri River Railroad in Nebraska; to

:umbull, president of the Colorado and Southern Railway Company; and e F. Bidwell, general manager of Fremont, Elkhorn and Missouri Valley for free transportation over their lines.

owledgments are also due to John C. Hoyt, George L. Warner, Stokes, and Frank H. Brundage, for computations on and the ement of data of this report.

VESTERN MISSISSIPPI RIVER DRAINAGE.

onvenience in arrangement, the stations from which the Geo- Survey has obtained data during 1902, and which are located ers tributary either directly or indirectly to the Mississippi rom the West, have been grouped under Missouri, Platte, Kan- kansas, and Red River drainage basins. These are arranged eport in this order.

MISSOURI RIVER DRAINAGE BASIN.

Missouri River is formed by the junction of the Jefferson, n, and Gallatin rivers at Three Forks, Mont. Of its tributa- e Marais des Cygnes River rises in the eastern part of Kansas, ist, and, as Osage River, enters the Missouri below Jefferson o. The Big Sioux River drains the extreme eastern part of Dakota and flows south into the Missouri at Sioux City, Iowa. obrara River drains the extreme northern part of Nebraska ws east into the Missouri at Niobrara, Nebr. The Yellowstone has its source in a lake of the same name in Yellowstone al Park, from which it takes a general northeasterly course and ito the Missouri near the Montana-North Dakota boundary. icipal tributaries are the Powder River, of which Clear Creek ney Creek in Wyoming are small tributaries near its head- and the Big Horn, which drains northeastern Wyoming, and h the Shoshone is a tributary. The Milk River rises on the in the northwestern part of Montana, flows northeast into and then, with a general easterly course, flows back into Mon- nptying into the Missouri in the northeastern part of the State. isselshell River rises in Meagher County, in south central Mon- ows east, then north into the Missouri, about 100 miles above uth of Milk River. The Marias River rises on the divide in the estern part of Montana and flows east into the Missouri. Two ie Creek is a tributary near its headwaters. West Gallatin the longest fork of the Gallatin, rises in Yellowstone Park and orth to its junction at Three Forks, Mont., with the Madison ferson Rivers. Middle Creek is a small tributary of the East n River. The Madison River rises in Yellowstone Park and orth parallel to the West Gallatin. The Jefferson River is

formed by the Beaverhead and Big Hole rivers. Its tributaries drain extreme southwestern Montana. The following is a list of the stations in the Missouri River drainage basin:

Marais des Cygnes River at Ottawa, Kans.
Big Sioux River near Watertown, S. Dak.
Niobrara River at Niobrara, Nebr.
Niobrara River at Valentine, Nebr.
Clear Creek at Buffalo, Wyo.
Piney Creek at Kearney, Wyo.
Shoshone River at Cody, Wyo.
Big Horn River near Thermopolis, Wyo.
Yellowstone River near Livingston, Mont.
Milk River at Malta, Mont.
Milk River at Havre, Mont.
Musselshell River at Shawmut, Mont.
Marias River near Shelby, Mont.
Two Medicine Creek at Midvale, Mont.
Missouri River at Cascade, Mont.
Missouri River at Townsend, Mont.
Gallatin River at Logan, Mont.
West Gallatin River near Salesville, Mont.
Middle Creek near Bozeman, Mont.
Madison River near Norris, near Redbluff, Mont.
Jefferson River at Sappington, Mont.

MARAIS DES CYGNES RIVER AT OTTAWA, KANS.

This station was established August 26, 1902, by W. G. Russell, and is located on the highway bridge near the center of the town of Ottawa, Kans. The gage is of the usual wire type, with the scale bar graduated to feet and tenths, and spiked to the bridge floor. The initial point for sounding is on the right bank. The channel both above and below the station is straight and the current quite swift. Both the right and left banks are high and the bed of the stream is rocky. The gage is read daily by W. H. Blacksten.

The following discharge measurements were made during 1902:

August 26: Gage height, 3.60 feet; discharge, 2,080 second-feet.
September 25: Gage height, 5.40 feet; discharge, 3,390 second-feet.
November 22: Gage height, 2.20 feet; discharge, 417 second-feet.

Daily gage height, in feet, of Marais des Cygnes River at Ottawa, Kans.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.						1902.					
1		13.50	4.00	1.90	2.50	17		1.80	2.20	2.70	2.30
2		9.15	2.60	1.90	2.30	18		1.80	2.10	2.40	2.20
3		3.20	2.40	1.90	2.50	19		1.70	2.10	2.40	2.10
4		2.40	13.70	2.00	4.70	20		1.80	2.00	2.30	4.80
5		2.20	22.25	2.40	3.00	21		1.80	2.00	2.20	11.60
6		6.30	22.30	2.40	2.40	22		2.90	2.00	2.20	7.60
7		15.90	16.20	2.20	2.30	23		7.00	2.00	2.20	3.50
8		9.60	3.30	2.10	2.20	24		12.75	2.00	2.20	2.90
9		2.90	2.80	2.00	2.20	25		7.20	2.00	2.40	2.50
10		2.30	2.60	2.00	2.20	26	3.60	3.50	2.00	2.40	2.40
11		2.10	2.50	2.00	2.10	27	2.80	2.70	1.90	2.30	2.40
12		2.10	2.40	1.90	2.30	28	2.50	2.40	1.90	2.20	2.30
13		2.00	2.40	2.00	2.30	29	2.30	2.20	1.90	2.10	2.30
14		2.00	2.30	2.00	2.30	30	2.20	4.50	1.90	2.10	2.20
15		1.90	2.20	3.70	2.20	31	7.45		1.90		2.20
16		1.90	2.20	3.40	2.20						

BIG SIOUX RIVER NEAR WATERTOWN, S. DAK.

Big Sioux River rises in Grant County, S. Dak., about 30 miles north of Watertown. Its principal headwaters drain lands constituting part of the Sisseton and Wahpeton Indian Reservation. Its general course is southeast, and it empties into Missouri River near Sioux City, Iowa. The river is of interest on account of its water powers, a number of which have been developed, principally at Flandreau, Dell Rapids, and Sioux Falls, S. Dak., and at Akron, Iowa.

Lake Poinsett, which lies almost wholly in Hamlin County, S. Dak., has its outlet in Big Sioux River near Dempster, a short distance above Estelline. Immediately below the outlet of the lake a dam has been constructed on the Big Sioux to maintain the level of the lake within certain limits.

The gaging station was established by O. V. P. Stout, the gage being put in September 15, 1900, by George W. Carpenter, county surveyor for Codington County. It is located on the farm of L. E. Spicer, about 4 miles above Watertown. The gage consists of an inclined rod securely fastened on the right bank of the stream. The observer is L. E. Spicer. During 1902 the following discharge measurements were made by A. B. Crane.

May 24: Gage height, 1.42 feet; discharge, 22 second-feet.
July 15: Gage height, 0.76 foot; discharge 2.3 second-feet.
November 15: Gage height 0.82 foot; discharge, 2.7 second-feet.

Daily gage height, in feet, of Big Sioux River at Watertown, S. Dak.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.							
1		1.15	0.88	0.70	0.91		
2							0.80
3		1.15		.70	.90	0.70	
4			.88				.80
5				.70		.70	
6		1.15	.88		.80		
7							.80
8		1.15	.85	.70	.70		
9						.73	.80
10		1.13		.70	.70		
11			.83				
12				.70		.70	.80
13		1.00	.80		.70		
14					.70	.70	.80
15		.90	.75	.72			
16					.70		.80
17		.85		.80		.69	
18			.75				.83
19				.80	.68	.69	
20		.83	.73				
21					.68	.68	.84
22		.83	.73	.83			
23					.70		.84
24		.85		.80		.68	
25	1.30		.70				.85
26				.80	.72	.78	
27	1.25	1.00	.70				
28					.73	.80	.85
29		.95	.70	.80			(a)
30	1.15				.72		
31						.80	

a Observations discontinued November 28 on account of ice.

NIOBRARA RIVER AT NIOBRARA, NEBR.

This station was established May 11, 1902, by J. C. Stevens. It is located at the wooden highway bridge 1 mile southwest of the city of Niobrara. The gage is of the usual wire type, graduated to feet and half-tenths. It is read daily by Miner Thompson, who lives near by. The measurements are taken from the bridge. The initial point of soundings is on the east end of the bridge on the upstream side. The channel is straight for a considerable distance both above and below the station. The banks are low, but not liable to overflow. The bed of the stream is sandy and shifting. The main channel seems to be changing from the right to the left bank. The zero-mark of the gage is 6.8 feet east of the face of the fourth floor beam from the west end of the bridge. From the index on the wire to the bottom of the sash weight is 19 feet. When the gage reads zero the water is

feet below the top of the face plate on the south pier at the west the bridge.

Discharge measurements of Niobrara River at Niobrara, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
	J. C. Stevens	2.55	1,637
	do	2.85	2,021
	do	2.00	1,401
21	do	2.10	1,106
ber 28	do	1.90	2,201

Daily gage height, in feet, of Niobrara River at Niobrara, Nebr.

Day.	May.	June.	July.	Aug.	Sept.	Oct.
1902.						
		2.60	2.70	2.70	2.60	2.40
		2.50	2.90	2.65	2.50	2.40
		2.50	2.95	2.65	2.50	2.40
		2.55	2.90	2.60	2.50	2.30
		2.70	2.80	2.60	2.45	2.30
		2.60	2.80	2.55	2.45	2.30
		2.60	2.70	2.55	2.50	2.25
		2.55	2.70	2.55	2.45	2.20
		2.70	2.75	2.60	2.40	2.20
		2.60	2.67	2.60	2.45	2.20
	2.55	2.50	2.60	2.70	2.40	2.10
	2.57	2.75	2.60	2.60	2.35	2.10
	2.57	2.60	2.60	2.55	2.40	2.10
	2.70	2.60	2.65	2.50	2.35	2.10
	2.70	2.60	2.60	2.70	2.30	2.05
	2.75	2.65	2.60	2.70	2.20	2.00
	2.57	2.75	2.60	2.75	2.30	2.10
	2.67	2.70	2.60	2.80	2.20	1.90
	2.80	2.65	2.65	2.85	2.20	1.90
	2.90	2.65	2.60	2.75	2.50	2.00
	3.00	2.75	2.60	2.70	2.90	2.00
	2.90	2.80	2.60	2.80	2.80	1.90
	2.57	2.80	2.55	2.70	2.80	1.90
	2.45	2.60	2.60	2.60	2.60	1.90
	2.40	2.60	2.65	2.75	2.60	1.90
	2.50	2.70	2.75	2.90	2.50	(a)
	2.50	2.85	2.70	2.75	2.50	.....
	2.60	2.70	2.70	2.65	2.50	.....
	2.55	2.80	2.70	2.60	2.45	.....
	2.50	2.75	2.70	2.55	2.40	.....
	2.45	.....	2.70	2.60	.....	.....

a Observations discontinued October 25, on account of ice.

NIOBRARA RIVER AT VALENTINE, NEBR.

A gaging station was established July 22, 1897, by O. V. P. Stout, and was known as the Fort Niobrara station. It was about three-quarters of a mile southwest from Fort Niobrara and about 3 miles east of Valentine, Nebr. The original gage was an oak rod 2 by 4 inches, graduated to tenths of a foot, and fastened in a vertical position by lag screws to a plumb post in the trestle bent which serves as the west pier of the military bridge near Fort Niobrara. The zero of the gage was 9.08 feet below the top of the short cap, at the shoe of the north truss at the west end of the bridge; it was also 8.09 feet below the top of the north end of the long pile cap, below the cap above noted; and also 9.17 feet lower than the top of the west side of the iron cap of the north cylinder of the center pier of the bridge. This station was afterwards discontinued, but was resumed on April 26, 1899, when a rod was located 195 feet downstream from the wagon bridge near Fort Niobrara. The rod was solidly bedded on cross-ties and well fastened with bridge spikes. It was a new 3 by 4 inch oak rod 10 feet long, and was placed on the left bank of the stream. Bench mark No. 1 was the top of a large spike driven in the top of a 2 by 4 inch timber which was set 4 feet in the ground and 12 feet west of the rod, and was 5.63 feet above gage datum. Bench mark No. 2 was the top of the short cap at shoe of truss at west end of the bridge, downstream side, and was 9.98 feet above the zero of the gage. Bench mark No. 3 was the top of the plate of the center pier of the bridge, downstream side, and was 10.03 feet above gage datum. Thomas Dillon, mail carrier between Valentine and Fort Niobrara, was the observer. On June 26, 1901, it was reestablished at the Borman bridge, which is about 3 miles upstream from the military bridge. The gage is of the wire and weight type, gage heights being marked by staples on the bridge rail. The zero of the gage is 12 feet below the top of the bridge floor.

Discharge measurements of Niobrara River at Valentine, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
March 22	J. C. Stevens	1.66	971
April 12	do	1.50	784
June 15	do	1.30	585
July 4	do	1.60	800
July 20	do	1.40	727
August 20	do	1.40	68
September 26	do	1.55	73
November 13	do	1.60	76

Daily gage height, in feet, of Niobrara River at Valentine, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.										
1	.....	1.58	1.63	1.50	8.10	1.31	1.40	1.42	1.58	1.55
2	.....	1.61	1.65	1.42	1.95	1.32	1.38	1.47	1.64	1.46
3	.....	1.64	1.60	1.44	1.73	1.38	1.30	1.42	1.53	1.16
4	.....	1.70	1.58	1.45	1.56	1.31	1.27	1.44	1.50	1.40
5	.....	1.68	1.65	1.54	1.58	1.42	1.28	1.47	1.57	1.48
6	.....	1.75	1.53	1.55	1.38	1.38	1.30	1.45	1.55	1.55
7	.....	1.50	1.47	1.44	1.25	1.31	1.27	1.44	1.54	(a)
8	.....	1.58	1.56	1.58	1.90	1.43	1.41	1.45	1.58	.....
9	(a)	1.54	1.60	1.42	1.38	1.48	1.28	1.46	1.54	.....
10	1.78	1.55	1.54	1.40	1.32	1.40	1.26	1.51	1.52	.....
11	1.80	1.44	1.52	1.42	1.32	1.24	1.33	1.53	1.50	.....
12	1.75	1.54	1.64	1.50	1.36	1.20	1.32	1.55	1.56	.....
13	1.79	1.58	1.57	1.48	1.27	1.36	1.29	1.52	1.60	.....
14	1.67	1.60	1.55	1.40	1.32	1.38	1.37	1.49	1.58	.....
15	1.65	1.54	1.63	1.28	1.26	1.39	1.33	1.48	1.56	.....
16	1.40	1.64	1.47	1.42	1.25	1.38	1.35	1.55	1.62	.....
17	1.33	1.72	1.52	1.47	1.26	1.44	1.34	1.52	1.56	.....
18	1.60	1.66	1.49	1.34	1.40	1.37	1.45	1.48	1.61	.....
19	1.95	1.58	1.83	1.52	1.42	1.38	1.40	1.50	1.54	.....
20	1.85	1.56	1.78	1.47	1.40	1.34	1.48	1.49	1.57	.....
21	2.05	1.47	1.51	1.36	1.34	1.45	1.45	1.48	1.50	.....
22	1.66	1.74	1.45	1.80	1.32	1.43	1.47	1.51	1.56	.....
23	1.75	1.69	1.51	1.32	1.37	1.34	1.33	1.55	1.52	.....
24	1.98	1.52	1.46	1.36	1.41	1.43	1.37	1.50	1.53	.....
25	1.90	1.80	1.44	1.33	1.32	1.62	1.48	1.51	1.60	.....
26	1.96	1.75	1.42	1.34	1.38	1.45	1.59	1.56	1.51	.....
27	1.93	1.54	1.48	1.37	1.35	1.31	1.53	1.53	1.56	.....
28	1.89	1.72	1.37	1.46	1.32	1.38	1.45	1.52	1.53	.....
29	1.83	1.58	1.40	1.95	1.34	1.40	1.57	1.51	1.46	.....
30	1.97	1.65	1.33	2.10	1.45	1.43	1.42	1.54	1.48	.....
31	1.85	.....	1.42	.....	1.36	1.52	.....	1.50	.....	.....

a Ice interfered with observations from January 1 to March 9 and from December 6 to 31.

Rating table for Niobrara River at Valentine, Nebr., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	475	1.3	580	1.6	865	1.9	1,330
1.1	490	1.4	655	1.7	1,000	2.0	1,525
1.2	525	1.5	750	1.8	1,155		

Estimated monthly discharge of the Niobrara River at Valentine, Nebr.

[Drainage area, 6,070 square miles.]

Month.	Discharge in second-feet.			Run-off.		
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
March, 22 days	.....	.....	1,169	51,011	0.19	0.16
April	1,155	700	896	53,310	.15	.17
May	1,240	615	802	49,305	.13	.15
June	1,740	580	740	44,030	.12	.13
July	4,260	580	805	49,490	.13	.15
August	865	525	653	40,145	.11	.13
September	865	550	649	38,614	.11	.12
October	805	655	745	45,805	.12	.14
November	930	700	807	48,015	.13	.15

CLEAR CREEK AT BUFFALO, WYO.

This station was established October 24, 1902, by Jeremiah Ahern. It is located at the highway bridge in the town of Buffalo, Johnson County, Wyo. The gage is a plain staff graduated to feet and tenths, spiked to the pier at the northwest end of the bridge. The initial point for sounding is on the left bank. Measurements are made from the bridge. The channel is straight both above and below the station. Both banks are high and rocky. The bed of the stream is also rocky. The gage is read daily by P. A. Gatchell. The bench mark is U. S. G. S. B. M. at the court-house, marked "SHER 4635." Elevation 4,635.033 feet. The elevation of the gage as determined from this bench mark is 4,605.766 feet.

Daily gage height, in feet, of Clear Creek at Buffalo, Wyo.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.			1902.			1902.			1902.		
1	.....	0.90	9	.....	1.00	17	0.70	1.00	25	0.85	0.80
2	.....	.90	10	.....	.80	18	.68	1.00	26	.90	.80
3	.....	.80	11	.....	.80	19	.70	.90	27	1.00	.75
4	.....	.80	12	.....	.90	20	.80	.85	28	1.00	.90
5	.....	.80	13	.....	.90	21	.70	.90	29	1.20	1.20
6	.....	.80	14	.....	.90	22	.70	.85	30	1.00	1.30
7	.....	.90	15	.....	1.10	23	.70	.85	31	.....	1.50
8	.....	.90	16	0.65	1.60	24	.80	.85			

PINEY CREEK AT KEARNEY, WYO.

This station was established September 6, 1902, by Jeremiah Ahern. It is located at the highway bridge at Kearney, Johnson County, Wyo., which is on the stage route between Sheridan and Buffalo, 24 miles from Sheridan. The gage is a vertical staff graduated to feet and tenths and spiked to the abutment of the bridge. It is read daily by R. D. Noyce. The initial point for sounding is on the right bank. Discharge measurements are taken from the bridge. The channel is straight for 600 feet above and 200 feet below the station. The left bank is high, and liable to overflow at extreme high water. The right bank is high and does not overflow. The bed of the stream is gravel. The bench mark is the U. S. G. S. bench mark at Geier's Ranch, about 600 feet from the gage. It is marked "SHER 4662." Elevation 4,661.767 feet. The elevation of the zero of the gage as referred to this bench mark is 4,645.963 feet.

The following discharge measurement was made in 1902, by J. Ahern.

September 6: Gage height, 1.41 feet; discharge, 21 second-feet.

Daily gage height, in feet, of Piney Creek at Kearney, Wyo.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1902.			1902.			1902.			1902.		
1		1.47	9	1.43	1.41	17	1.48	1.39	25	1.42	1.44
2		1.43	10	1.43	1.40	18	1.49	1.39	26	1.47	
3		1.43	11	1.43	1.41	19	1.48	1.38	27	1.60	
4		1.42	12	1.43	1.40	20	1.47	1.39	28	1.43	
5		1.41	13	1.43	1.39	21	1.48	1.39	29	1.50	
6		1.41	14	1.43	1.40	22	1.46	1.40	30	1.40	
7	1.45	1.40	15	1.43	1.40	23	1.45	1.55			
8	1.43	1.42	16	1.48	1.40	24	1.43	1.46			

SHOSHONE RIVER AT CODY, WYO.

This station was established April 26, 1902, by A. J. Parshall. It is located at the wagon bridge 1 mile northwest of Cody, Wyo. The gage is a plain staff graduated to one-half tenths and is fastened to the bridge, from which discharge measurements are made. The initial point for sounding is on the left bank. The channel is straight both above and below the station. The current is swift. The right bank is low and subject to overflow. The left bank is high and does not overflow. The bed of the stream is gravel and rock. The bench mark is a bolt in the bridge sleeper 1.15 feet above the 12-foot mark on the gage. It is indicated by a cross. The observer is W. J. Kissick, who reads the gage twice daily.

During 1902 the following discharge measurements were made by A. J. Parshall:

April 26: Gage height, 2.40 feet; discharge, 538 second-feet.
June 7: Gage height, 4.80 feet; discharge, 4,352 second-feet.
July 17: Gage height, 4.10 feet; discharge, 2,812 second-feet.
July 31: Gage height, 3.65 feet; discharge, 2,039 second-feet.
December 8: Gage height, 2.00 feet; discharge, 270 second-feet.

Daily gage height, in feet, of Shoshone River at Cody, Wyo.

Day.	May.	June.	July.	Aug.	Sept.	Oct.
1902.						
1	2.75	5.50	4.15	4.00	2.50	2.50
2	3.00	5.00	4.45	4.00	2.50	2.50
3	2.55	4.50	4.65	4.00	2.50	2.50
4	2.50	4.50	4.45	3.45	2.50	2.50
5	2.50	5.00	4.00	3.40	2.50	2.50
6	2.60	5.00	4.05	3.50	2.50	2.50
7	3.00	4.80	4.00	3.45	2.50	2.50
8	3.55	5.60	4.00	3.50	2.50	2.50
9	4.00	6.00	4.00	3.50	2.50	2.50
10	4.20	6.60	4.05	3.15	2.50	2.50
11	4.40	6.60	4.20	3.00	2.50	2.50
12	4.15	6.30	4.50	3.00	2.50	2.50
13	4.30	6.30	4.50	3.00	2.50	2.50
14	4.50	6.00	4.45	3.00	2.50	2.50
15	4.90	5.40	4.45	3.00	2.50	2.50
16	4.50	5.00	4.25	3.00	2.50	2.50
17	4.35	5.00	4.25	3.00	2.50	2.50
18	4.40	5.00	4.25	3.00	2.50	2.50
19	4.10	4.70	4.35	3.00	2.50	2.50
20	3.65	4.50	4.00	3.00	2.50	2.50
21	3.50	5.00	4.00	3.00	2.50	2.50
22	3.50	4.90	4.10	3.00	2.50	2.50
23	3.50	5.25	4.10	3.00	2.50	2.50
24	3.50	5.25	4.00	3.00	2.50	2.50
25	3.50	5.25	4.00	3.00	2.50	2.50
26	3.90	5.25	4.00	3.00	2.50	2.50
27	4.75	5.00	4.00	3.00	2.50	2.50
28	5.25	4.85	4.10	3.00	2.50	2.50
29	5.25	4.50	4.20	3.00	2.50	2.50
30	5.50	4.50	4.00	3.00	2.50	2.50
31	5.75	.....	4.00	2.50	.....	2.50

Rating table for Shoshone River at Cody, Wyo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.5	30	2.8	860	4.1	2,920	5.4	5,585
1.6	70	2.9	960	4.2	3,125	5.5	5,790
1.7	110	3.0	1,070	4.3	3,330	5.6	5,995
1.8	160	3.1	1,190	4.4	3,535	5.7	6,200
1.9	210	3.2	1,320	4.5	3,740	5.8	6,405
2.0	270	3.3	1,460	4.6	3,945	5.9	6,610
2.1	335	3.4	1,610	4.7	4,150	6.0	6,815
2.2	400	3.5	1,770	4.8	4,355	6.1	7,020
2.3	470	3.6	1,940	4.9	4,560	6.2	7,225
2.4	540	3.7	2,120	5.0	4,765	6.3	7,430
2.5	615	3.8	2,310	5.1	4,970	6.4	7,635
2.6	690	3.9	2,510	5.2	5,175	6.5	7,840
2.7	770	4.0	2,715	5.3	5,380		

Estimated monthly discharge of Shoshone River at Cody, Wyo.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
May	6,300	615	2,752	168,904
June	8,045	3,740	5,246	311,632
July	4,045	2,715	2,755	169,112
August	2,715	615	1,346	82,762
September	615	615	615	37,749
October	615	615	615	37,749

BIGHORN RIVER NEAR THERMOPOLIS, WYO.

This station, which was established by A. J. Parshall on May 28, 1900, was located about a half mile northeast of Thermopolis, at the ferry crossing the river. The gage, which consists of a horizontal rod extending out over the water, is fastened to a post set firmly in the bank. On the horizontal stick is attached the wire gage by means of which the heights of the river are recorded. The bench mark was the head of a nail in a stick driven in the ground 1 foot south of the post to which the gage rod is fastened and 2.58 feet below the top of the gage frame. The bench mark has been destroyed. A new gage, whose relative heights are the same as those of the gage of 1901, was painted on a pier on the right bank in 1903. This gage is reached only by the

water when it is at a height of 3 feet above datum. It will enable the observer to read heights of high water more accurately than can be done upon the gage rod which is in the center of the stream and is exposed to the force of the current, causing a rise and fall of several inches on the rod. Discharge measurements were first made from a ferryboat, but, beginning with 1902, they have been made from the bridge which was recently erected. The channel is straight above and below the station. Both banks are high and not subject to overflow. The bed of the stream is of gravel and shifts during extreme high water. In 1901 a gage was painted upon one of the lower piers of the new State bridge over the river, 400 or 500 feet upstream from the former station. The relative heights on the rod remained as before, the same bench mark being used. During 1902 the following discharge measurements were made by A. J. Parshall:

June 11: Gage height, 4.70 feet; discharge, 9,080 second-feet.
June 14: Gage height, 4.40 feet; discharge, 8,391 second-feet.
June 16: Gage height, 3.60 feet; discharge, 6,334 second-feet.

Daily gage height, in feet, of Bighorn River near Thermopolis, Wyo.

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1902.					1902.				
1	2.40	2.80	2.70	0.90	17	3.40	1.50	2.10	0.7[illegible]
2	2.60	2.80	2.60	.80	18	3.40	1.50	2.10	.6[illegible]
3	2.70	2.70	2.60	.80	19	3.30	1.50	2.00	.6[illegible]
4	2.70	2.60	2.60	.80	20	2.90	1.40	1.90	.6[illegible]
5	2.60	2.50	2.50	.70	21	2.40	1.40	1.80	.6[illegible]
6	2.40	2.30	2.50	.70	22	2.50	1.40	1.70	.5[illegible]
7	3.40	2.10	2.40	.60	23	2.40	1.30	1.60	.50
8	3.70	2.00	2.30	.60	24	2.30	1.30	1.60	1.00
9	4.20	2.00	2.30	.90	25	2.20	1.40	1.50	1.00
10	4.20	1.90	2.20	1.00	26	2.30	2.50	1.40	.90
11	4.70	1.80	2.20	1.20	27	2.20	3.00	1.20	.90
12	5.00	1.80	2.30	1.00	28	2.10	3.00	1.10	.80
13	4.60	1.70	2.30	.90	29	2.30	3.00	1.00	.60
14	4.40	1.70	2.20	.80	30	2.40	2.90	.90	.50
15	4.00	1.60	2.10	.80	31	.....	2.80	.90	.....
16	3.60	1.50	2.10	.70					

YELLOWSTONE RIVER NEAR LIVINGSTON, MONT.

The gaging station is located at the highway bridge over the Yellowstone River, 5 miles south of Livingston, Mont., at the mouth of the canyon. It was established May 2, 1897, a vertical rod fastened to the face of the pier being first used. A wire gage was afterwards established. Length of cable 18.30 feet; pulley distance, 0.58 foot. The bench mark is the head of the 2-inch nut on the center pin at the foot of the end diagonal of the truss, east pier, upper side, and is 13.44 feet above datum.

A new bench mark was determined in 1899. It was the top of the end plate of the bridge at the upper side of the east end, at an elevation of 14.20 feet above zero of gage. On January 1, 1903, the gage (and the datum) were lowered 3.00 feet, making all subsequent readings 3 feet greater. The elevation of bench mark also reads 17.20 feet, instead of 14.20 feet. The slope of the water surface at the gaging station was found to be 0.146 feet in 200 feet on August 29, 1899. The left bank is high and will not overflow. The right bank is low, and during floods a part of the water escapes through a slough on that side, and has to be measured separately. The observer is Thomas S. Carter, rancher.

During 1902 the following discharge measurements were made by H. B. Waters:

May 1: Gage height, −0.82 foot; discharge, 1,604 second-feet.
July 16: Gage height, 2.90 feet; discharge, 8,359 second-feet.
August 23: Gage height, 0.23 foot; discharge, 3,081 second-feet.

Daily gage height, in feet, of Yellowstone River near Livingston, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	−1.30	(a)	−1.20	−1.20	−0.75	5.15	3.50	1.52	−0.05	−0.05	−1.05	−1.30
2	−1.30	(a)	−1.15	−1.15	−.80	4.20	3.50	1.42	−.10	−.70	−1.05	−1.30
3	−1.00	−1.60	−1.20	−1.15	−.80	3.70	3.77	1.32	−.10	−.70	−1.10	−1.40
4	−.90	−1.50	−1.20	−1.15	−.80	3.60	3.57	1.20	−.15	−.70	−1.10	−1.40
5	−1.00	−1.40	−1.25	−1.15	−.75	3.90	3.50	1.15	−.20	−.75	−1.25	−1.30
6	−1.10	−1.40	−1.20	−1.10	−.75	3.90	3.30	1.05	−.20	−.75	−1.30	−1.40
7	−1.00	−1.40	−1.20	−1.10	−.45	3.90	3.20	1.00	−.25	−.75	−1.20	(a)
8	−1.00	−1.40	−1.20	−1.10	−.15	4.25	3.05	.95	−.25	−.80	1.05	−1.60
9	−1.00	(a)	−1.25	−1.15	.75	5.20	2.92	.90	−.30	−.80	1.05	−1.30
10	−1.00	−1.20	−1.20	−1.15	1.38	5.90	2.90	.85	−.30	−.80	1.05	−1.30
11	−1.10	−1.10	−1.20	−1.12	1.78	6.05	2.90	.80	−.35	−.80	1.00	−1.40
12	(a)	−1.10	−1.20	−1.12	1.98	5.80	2.97	.80	−.40	−.80	1.00	−1.40
13	−1.30	−1.10	−1.20	−1.15	2.70	5.50	3.00	.80	−.45	−.85	1.00	−1.30
14	−1.30	−1.20	−1.30	−1.15	3.03	5.85	3.00	.75	−.45	−.85	−1.00	(a)
15	−1.20	−1.20	−1.25	−1.15	3.65	4.65	2.90	.75	−.50	−.85	−1.05	1.60
16	−1.30	−1.00	−1.20	−1.10	3.28	4.32	2.80	.70	−.50	−.90	−1.10	−1.70
17	−1.30	−.90	−1.20	−1.05	3.35	4.07	2.77	.70	−.50	−.90	−1.10	−1.60
18	−1.10	−1.00	−1.20	−.95	2.88	4.00	2.62	.70	.50	.90	−1.10	−1.60
19	−1.15	−1.00	−1.20	−.80	2.43	3.85	2.45	.65	−.50	−.95	−1.15	−1.50
20	−1.20	−1.20	−1.20	−.35	1.93	3.67	2.35	.60	−.55	−.95	−1.15	−1.40
21	−1.30	−1.20	−1.20	−.60	1.78	3.77	2.30	.50	−.55	−.95	−1.25	−1.40
22	−1.20	−1.20	−1.20	−.90	1.50	3.90	2.28	.40	−.60	−.95	−1.35	−1.40
23	−1.50	−1.20	−1.20	−.60	1.43	4.05	2.20	.35	−.60	−1.00	−1.30	−1.30
24	(a)	−1.20	−1.20	−.70	1.55	4.13	2.15	.30	−.60	−1.00	−1.25	−1.40
25	(a)	−1.20	−1.20	−.80	2.13	4.00	2.10	.25	−.60	−1.00	−1.20	−1.20
26	(a)	−1.20	−1.15	−.90	2.68	4.03	2.02	.20	−.65	−1.00	−1.30	−1.10
27	(a)	−1.20	−1.15	−.90	3.58	3.85	1.92	.15	−.65	−1.00	−1.35	−1.30
28	(a)	−1.20	−1.20	−.90	4.25	3.90	1.80	.10	.65	1.00	−1.35	(a)
29	(a)	.....	−1.35	−.85	4.55	3.55	1.75	.05	−.65	1.00	−1.35	−1.50
30	(a)	.....	−1.35	−.80	5.10	3.60	1.70	.00	−.65	−1.00	−1.45	−1.50
31	(a) −1.60	.....	−1.30	.....	5.40	.....	1.62	.00	.....	1.05	.....	−1.50

a River frozen at gage.

Rating table for Yellowstone River near Livingston, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
−1.6	1,000	0.4	3,445	2.4	7,375	4.4	11,350
−1.4	1,135	.6	3,840	2.6	7,765	4.6	11,750
−1.2	1,280	.8	4,225	2.8	8,155	4.8	12,150
−1.0	1,440	1.0	4,620	3.0	8,545	5.0	12,550
− .8	1,640	1.2	5,010	3.2	8,950	5.2	12,950
− .6	1,825	1.4	5,395	3.4	9,350	5.4	13,350
− .4	2,070	1.6	5,790	3.6	9,750	5.6	13,750
− .2	2,350	1.8	6,195	3.8	10,150	5.8	14,150
.0	2,680	2.0	6,590	4.0	10,550	6.0	14,550
.2	3,050	2.2	6,985	4.2	10,950	6.2	14,950

Estimated monthly discharge of Yellowstone River near Livingston, Mont.

[Drainage area, 3,580 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean		Second-feet per square mile.	Depth in inches.
1902.						
January	1,550	1,000	1,242	76,368	0.35	0.40
February	1,550	1,000	1,254	69,644	.35	.36
March	1,317	1,170	1,268	77,966	.35	.40
April	2,137	1,280	1,479	88,007	.41	.46
May	13,350	1,640	6,392	393,029	1.79	2.06
June	14,650	9,650	11,230	668,231	3.14	3.50
July	10,050	5,790	7,899	485,691	2.21	2.55
August	5,590	2,680	3,974	244,352	1.11	1.28
September	2,592	1,770	2,053	122,162	.57	.64
October	1,770	1,397	1,564	96,167	.44	.51
November	1,440	1,135	1,309	77,891	.37	.41
December	1,355	960	1,129	69,420	.32	.37
The year	14,650	960	3,402	2,468,928	.95	12.94

MILK RIVER AT MALTA, MONT.

This station was established July 31, 1902, by C. T. Prall. It is located at the highway bridge on the main road one-fourth mile east of Malta, Mont. The gage is of the usual wire type, with the scaleboard graduated to feet and tenths and nailed to the lower

the bridge. The length of the gage wire from the pointer end of the weight is 28.7 feet. The distance from the zero .rod to the outside edge of the pulley is 0.5 of a foot. The s read twice daily by H. Caselberg. The initial point for ng is on the right bank. The channel is straight for 700 feet the station and 250 feet below the station. The banks are not to overflow. The bed of the stream is rocky and sandy. The mark is a 20-penny wire nail driven just below the gage rod ıge reading of 5 feet.

Discharge measurements of Milk River at Malta, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
.....	C. T. Prall	2.50	525
21	do	1.80	259
ber 10	do	1.40	166
ber 25	F. E. Weymouth	1.50	165
·6	John T. Whistler	1.85	271
·11	F. E. Weymouth	1.65	198
·17	Cyrus C. Babb	1.67	174
·24	John T. Whistler	1.60	171
·31	George Drummond	1.70	257
ber 7	John T. Whistler	1.70	210

Daily gage height, in feet, of Milk River at Malta, Mont.

y.	Aug.	Sept.	Oct.	Nov.	Day.	Aug.	Sept.	Oct.	Nov.
2.					1902.				
.....	2.30	1.80	1.70	1.60	17	1.70	1.30	1.60	.....
.....	2.40	1.70	1.70	1.60	18	1.80	1.30	1.60	.....
.....	2.30	1.70	1.70	1.60	19	1.80	1.30	1.60	.....
.....	2.20	1.70	1.70	1.60	20	1.70	1.30	1.60	.....
.....	2.10	1.70	1.70	1.60	21	1.70	1.30	1.60	.....
.....	2.10	1.70	1.70	1.60	22	1.80	1.30	1.60	.....
.....	2.10	1.70	1.70	1.60	23	1.70	1.30	1.60	.....
.....	2.10	1.60	1.70	1.70	24	1.80	1.30	1.60	.....
.....	2.10	1.50	1.70	.....	25	1.80	1.30	1.60	.....
.....	2.00	1.50	1.80	.....	26	1.80	1.40	1.60	.....
.....	1.95	1.50	1.80	.....	27	1.80	1.40	1.60	.....
.....	1.90	1.40	1.60	.....	28	1.70	1.30	1.60	.....
.....	1.90	1.30	1.60	.....	29	1.70	1.30	1.60	.....
.....	1.90	1.30	1.60	.....	30	1.70	1.40	1.60	.....
.....	1.90	1.30	1.60	.....	31	1.70	.....	1.60	.....
.....	1.70	1.30	1.60	.....					

Rating table for Milk River at Malta, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.6	32	2.4	485	4.2	1,187	6.0	1,889
0.8	47	2.6	563	4.4	1,265	6.2	1,967
1.0	68	2.8	641	4.6	1,343	6.4	2,045
1.2	93	3.0	719	4.8	1,421	6.6	2,123
1.4	127	3.2	797	5.0	1,499	6.8	2,201
1.6	173	3.4	875	5.2	1,577	7.0	2,279
1.8	251	3.6	953	5.4	1,655		
2.0	329	3.8	1,031	5.6	1,733		
2.2	407	4.0	1,109	5.8	1,811		

Estimated monthly discharge of Milk River at Malta, Mont.

[Drainage area, 6,744 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
August	485	212	294	18,056	0.04	0.0
September	251	109	143	8,509	.02	.0
October	251	173	189	11,620	.03	.0
November 1 to 8	.....	.....	178	2,822	.03	.0

MILK RIVER AT HAVRE, MONT.

The present station is located at Havre, Mont., and was establishe by Cyrus C. Babb, May 15, 1898. Measurements of discharge ar made from a car and cable of 200-foot span swung across the river short distance above the gage. The river is subject to violent flood of short duration, and the bed of the river being composed of gravel and clay is liable to change after each freshet.

Discharge measurements of Milk River at Havre, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
l	J. S. Baker	3.50	249
)	L. H. Ling	3.10	214
	do	4.00	362
	do	4.90	1,013
	do	7.35	3,363
	do	8.88	5,179
	do	6.60	2,503
	do	7.00	2,341
	do	4.70	573
8	do	4.10	387
26	do	4.20	427
30	do	3.90	269
ber 11	do	3.60	192
ber 17	do	3.80	240
ber 23	do	3.90	226
ber 30	do	4.00	229
6	do	3.90	206
16	do	3.90	208
29	do	3.90	206
ber 4	L. V. Branch	3.77	205

Daily gage height, in feet, of Milk River at Havre, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov
1902.											
1	.....	.....	4.20	2.80	3.10	4.30	4.60	4.70	3.90	4.00	3.9
2	.....	.....	4.20	2.80	3.20	4.30	4.60	4.60	3.90	3.90	4.0
3	.....	.....	4.20	2.80	3.20	6.40	5.00	4.30	3.90	3.90	4.0
4	.....	(a)	4.00	3.60	3.10	7.40	6.50	4.20	3.80	3.90	3.8
5	.....	.....	3.90	3.50	3.10	8.40	7.50	4.20	3.80	3.90	3.8
6	.....	.....	3.40	3.40	3.00	8.00	8.00	4.10	3.80	3.90	3.8
7	.....	.....	3.20	3.10	3.00	8.00	12.10	4.10	3.80	3.90	3.8
8	.....	.....	3.20	3.10	3.00	6.00	10.50	4.10	3.80	3.90	(a)
9	a 3.00	.....	3.20	3.10	3.10	5.50	8.00	4.10	3.80	3.80	.....
10	.....	.....	3.60	3.10	3.10	5.40	7.00	4.10	3.60	3.80	.....
11	.....	.....	4.30	3.50	3.20	5.20	6.40	4.10	3.60	3.80	.....
12	.....	.....	4.00	3.70	3.20	5.00	6.00	4.10	3.60	3.90	.....
13	.....	.....	3.40	3.70	3.20	5.00	6.20	4.10	3.60	3.90	(a)
14	.....	.....	3.20	3.60	3.20	4.90	6.20	4.10	3.60	3.90	.....
15	.....	(a)	3.20	3.50	3.20	4.80	6.00	4.10	3.60	3.90	.....
16	.....	.....	3.20	3.50	3.30	5.20	6.00	4.00	3.80	3.90	.....
17	.....	.....	3.20	3.30	3.40	5.20	5.50	4.00	3.80	3.90	.....
18	a 3.00	.....	3.20	3.20	4.00	5.20	5.20	4.00	3.70	3.90	(a)
19	.....	3.30	3.20	3.10	4.00	5.20	5.00	4.00	3.60	3.90	.....
20	.....	3.60	3.20	3.00	4.10	5.20	5.20	4.00	3.60	3.90	.....
21	.....	3.30	3.20	2.90	4.10	5.20	5.20	4.00	3.60	3.90	.....
22	.....	3.30	3.20	2.90	5.10	5.20	5.00	4.00	3.80	3.90	.....
23	.....	3.10	3.20	3.00	7.80	5.10	5.20	3.90	3.90	3.90	(a)
24	.....	3.10	3.40	3.00	10.50	5.10	5.20	3.90	3.90	3.90	.....
25	a 3.00	3.10	3.50	3.00	11.00	5.00	5.20	4.00	4.00	3.90	.....
26	.....	3.10	3.60	3.00	7.30	4.90	5.00	4.20	4.00	3.90	.....
27	.....	3.40	3.60	2.90	6.60	4.80	4.90	4.10	3.90	3.90	.....
28	.....	3.40	3.50	2.90	5.60	4.80	4.90	4.00	3.90	3.90	(a)
29	.....	.....	3.20	2.90	5.00	4.60	4.80	4.00	3.90	3.90	.....
30	a 2.00	.....	2.90	3.00	4.50	4.60	4.70	3.90	4.00	3.90	.....
31	.....	.....	2.90	.....	4.50	.....	4.70	3.90	.....	3.90	.....

a Frozen at gage.

Rating table for Milk River at Havre, Mont., for 1902.

FROM JANUARY 1 TO MAY 22.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Disch
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Secon*
2.6	145	5.0	989	7.4	3,442	9.8	6,
2.8	161	5.2	1,178	7.6	3,677	10.0	6,
3.0	180	5.4	1,368	7.8	3,912	10.2	6,
3.2	200	5.6	1,557	8.0	4,147	10.4	6,
3.4	222	5.8	1,746	8.2	4,381	10.6	7,
3.6	250	6.0	1,935	8.4	4,616	10.8	7,
3.8	288	6.2	2,124	8.6	4,851	11.0	7,
4.0	335	6.4	2,314	8.8	5,086	11.5	8,
4.2	412	6.6	2,503	9.0	5,320	12.0	8,
4.4	519	6.8	2,738	9.2	5,555	12.5	9,
4.6	630	7.0	2,973	9.4	5,790		
4.8	800	7.2	3,207	9.6	6,025		

Rating table for Milk River at Havre, Mont., for 1902—Continued.

FROM MAY 23 TO DECEMBER 31.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.6	100	3.0	122	3.4	157	3.8	212
2.8	109	3.2	138	3.6	180	4.0	300

[a] Above 4 feet the table is the same as for the fore part of the year.

Estimated monthly discharge of Milk River at Havre, Mont.

[Drainage area 7,300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	180	180	180	11,068	0.02	0.02
February			[a] 208	11,552	.03	.03
March	465	170	249	15,310	.03	.03
April	268	161	196	11,663	.03	.03
May	7,668	180	1,085	66,714	.15	.17
June	4,616	465	1,479	88,007	.20	.22
July	8,960	630	2,045	125,742	.28	.32
August	710	310	377	23,181	.05	.06
September	335	250	297	17,673	.04	.04
October	335	288	309	18,999	.04	.04
November			[a] 300	17,851	.04	.04
December			[a] 300	18,466	.04	.04
The year	8,960	161	586	426,226	.08	1.04

[a] Frozen; estimated.

MUSSELSHELL RIVER AT SHAWMUT, MONT.

This station was established August 12, 1902, by S. B. Dobbins. It is located about 200 yards west of Shawmut post-office, which is at the home ranch of the Blooming Land and Cattle Company. The gage is a vertical pole, graduated to feet and tenths, and nailed to a stump which overhangs the river. The observer is Dwight Crawford, who reads the gage daily. No bench marks have been established. The barometric elevation at this station is 3,900 feet.

Daily gage height, in feet, of Musselshell River at Shawmut, Mont.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec
1902.						1902.					
1		0.60	1.00	1.10	1.10	17	0.70	0.70	1.10	1.20	1
2		.60	1.00	1.10	1.10	18	.70	.70	1.10	1.20	1
3		.60	1.00	1.10	1.10	19	.70	.70	1.10	1.10	1
4		.60	1.00	1.20	1.10	20	.70	.80	1.10	1.10	
5		.60	1.00	1.00	1.20	21	.70	.70	1.10	1.00	
6		.50	1.00	1.80	1.20	22	.70	.70	1.10	1.00	
7		.50	1.00	1.10	1.20	23	.70	.70	1.10	1.10	
8		.50	1.00	1.20	1.20	24	.70	.70	1.10	1.20	
9		.50	1.00	1.20	1.20	25	.60	.70	1.10	1.20	
10		.70	1.00	1.20	1.20	26	.60	.70	1.10	1.20	
11		.70	1.10	1.20	1.20	27	.80	.70	1.10	1.20	
12	0.60	.70	1.10	1.20	1.20	28	.70	.80	1.10	1.20	
13	.50	.70	1.10	1.20	1.20	29	.60	.90	1.10	1.20	
14	.50	.70	1.10	1.20	1.20	30	.60	.90	1.20	1.10	
15	.50	.70	1.10	1.20	1.20	31	.60		1.20		
16	.60	.70	1.10	1.20	1.20						

MARIAS RIVER NEAR SHELBY, MONT.

This station was established April 4, 1902, by J. S. Baker. l located on the highway bridge 7 miles south of Shelby, Mont. ' gage is of the usual wire type. The scaleboard is spiked to the do stream face of the bridge and is graduated to feet and tenths. l read daily by William Mead, who lives about one-half mile southv of the gage. The right bank is low and liable to overflow. The bank is high and confined by a row of piles and a plank wall. ' bed of the stream is composed of sand and gravel. Above the sta the channel is curved. Below the station it is straight. The ini point for sounding is on the left bank at the east edge of the east on the lower side of the bridge. Bench mark No. 1 is a rivet hea the footplate at the foot of the batter post on the top of the sou east pier of the bridge. It is marked with black paint, B. M. 17 Its elevation above the zero of the gage is 17.54 feet. B. M. No. a spike in the southwest side of a cottonwood stump 25 feet south of the southeast pier. It is marked B. M. 11.27. Its elevation ab the zero of the gage is 11.27 feet.

Discharge measurements of Marias River near Shelby, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 4	J. S. Baker	2.05	358
April 4	do	2.05	357
July 8	L. V. Branch	5.95	5,664
July 23	do	3.68	1,658
July 29	C. T. Prall	3.40	1,295
August 15	C. C. Babb	2.80	780
September 19	C. T. Prall	2.40	547
November 3	L. V. Branch	2.16	299

Daily gage height, in feet, of Marias River near Shelby, Mont.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
1		2.70	6.50	4.10	3.10	2.40	2.20	2.20	2.30
2		2.70	6.40	5.00	3.10	2.30	2.20	2.20	2.30
3		2.90	6.20	6.40	3.00	2.20	2.20	2.20	2.30
4	2.50	2.70	5.50	11.50	3.00	2.30	2.20	2.20	2.30
5	2.60	2.60	5.20	11.00	3.00	2.40	2.20	2.20	2.30
6	2.40	2.50	5.00	8.50	2.90	2.40	2.20	2.10	2.30
7	2.10	2.60	4.90	6.80	2.80	2.40	2.20	2.20	2.30
8	2.10	2.90	4.80	6.10	2.70	2.30	2.20	2.20	2.30
9	2.00	3.00	4.50	5.60	2.80	2.20	2.20	2.10	2.30
10	2.10	3.30	4.80	5.30	3.00	2.10	2.20	2.20	2.30
11	2.10	3.30	5.10	5.10	2.80	2.20	2.20	2.20	2.30
12	2.10	3.90	5.10	4.90	2.70	2.20	2.20	2.30	2.50
13	2.10	3.90	4.90	4.50	2.50	2.20	2.20	2.70	2.60
14	2.10	3.90	4.60	4.50	2.50	2.20	2.20	2.60	2.60
15	2.20	4.40	4.50	4.50	2.50	2.20	2.20	2.60	2.50
16	1.90	5.70	4.40	4.40	2.40	2.30	2.20	2.50	2.60
17	2.00	5.40	4.50	4.40	2.40	2.20	2.20	2.60	2.50
18	2.00	5.10	4.40	4.10	2.50	2.20	2.20	2.50	2.50
19	2.00	5.10	4.20	4.10	2.20	2.30	2.20	2.50	2.50
20	2.00	4.90	4.20	4.00	2.10	2.20	2.20	2.50	2.60
21	2.50	9.90	4.10	4.00	2.10	2.20	2.20	2.40	2.60
22	2.70	14.50	4.00	3.90	2.30	2.50	2.20	2.50	2.50
23	2.60	9.20	4.10	3.80	2.00	2.40	2.20	2.50	2.50
24	2.50	9.40	3.90	3.60	2.40	2.20	2.20	2.50	2.50
25	2.40	9.00	4.10	3.50	2.60	2.30	2.20	2.40	2.50
26	2.30	6.40	4.10	3.60	2.70	2.20	2.20	2.40	2.60
27	2.40	6.00	4.40	3.60	2.50	2.20	2.20	2.30	2.60
28	2.40	6.50	4.30	3.70	2.50	2.20	2.20	2.30	2.60
29	2.40	6.60	4.20	3.50	2.30	2.30	2.20	2.30	2.40
30	2.60	7.00	4.30	3.30	2.20	2.30	2.20	2.30	2.30
31		6.60		3.30	2.10		2.20		2.30

Rating table for Marias River near Shelby, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	144	3.8	1,871	6.6	6,809	9.4	11,737
1.2	168	4.0	2,223	6.8	7,161	9.6	12,089
1.4	192	4.2	2,575	7.0	7,513	9.8	12,441
1.6	227	4.4	2,927	7.2	7,865	10.0	12,793
1.8	273	4.6	3,279	7.4	8,217	10.2	13,145
2.0	333	4.8	3,631	7.6	8,569	10.4	13,497
2.2	425	5.0	3,983	7.8	8,921	10.6	13,849
2.4	540	5.2	4,355	8.0	9,273	10.8	14,201
2.6	660	5.4	4,707	8.2	9,625	11.0	14,553
2.8	780	5.6	5,059	8.4	9,977	11.2	14,905
3.0	935	5.8	5,401	8.6	10,329	11.4	15,257
3.2	1,105	6.0	5,753	8.8	10,681	11.6	15,609
3.4	1,285	6.2	6,105	9.0	11,033	11.8	15,961
3.6	1,520	6.4	6,457	9.2	11,385	12.0	16,313

Estimated monthly discharge of Marias River near Shelby, Mont.

[Drainage area, 2,610 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth inches
1902.						
April 4 to 30			468	25,063	0.18	0.1
May	5,235	600	4,764	292,927	1.83	2.1
June	6,633	2,047	3,469	206,420	1.33	1.4
July	16,313	1,190	3,980	244,721	1.52	1.7
August	1,402	333	654	40,213	.25	.2
September	600	373	463	27,550	.18	.2
October	480	425	425	26,132	.16	.1
November	720	373	518	30,823	.20	.2
December	660	480	563	34,617	.22	.2

TWO MEDICINE CREEK AT MIDVALE, MONT.

This station was established September 17, 1902, by C. C. Babb It is located 200 yards above the Great Northern Railroad bridge mile from the railroad station at Midvale, Mont. The gage is incline and graduated so as to give readings of vertical feet and tenths. I is fastened to a tree and stake. The initial point for sounding is o the left bank. The channel is straight for 700 feet above and 300 fe

low the station. The banks are high and rocky. Bench mark No. s a nail in a rock 13.5 feet below the rod. Its elevation is 2.03 feet ove the zero of the gage. Bench mark No. 2 is a nail driven in a ruce tree 40 yards north of the rod. Its elevation is 32 feet above e zero of the gage.

The following discharge measurements were made during 1902:

October 15: Gage height, 0.45 foot; discharge, 34 second-feet.
October 15: Gage height, 0.54 foot; discharge, 47 second-feet.

Daily gage height, in feet, of Two Medicine Creek at Midvale, Mont.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.				
1		0.50	0.35	0.70	17		0.45	1.50	0.80
2		.50	.35	.60	18	0.45	.45	1.20	.80
3		.50	.35	.60	19	.50	.45	1.00	.80
4		.50	.30	.60	20	.45	.45	1.00	.80
5		.50	.30	.60	21	.45	.40	.90	.80
6		.45	.30	.60	22	.45	.40	.90	.80
7		.45	.30	.60	23	.40	.40	.80	.80
8		.45	.30	.60	24	.40	.35	.80	.80
9		.45	.30	.70	25	.40	.35	.80	.90
10		.45	.35	.70	26	.45	.35	.70	1.00
11		.50	.40	.80	27	.50	.35	.70	1.00
12		.50	.55	.80	28	.50	.35	.70	1.20
13		.45	.70	.80	29	.50	.35	.70	1.20
14		.45	.90	.80	30	.50	.35	.70	1.20
15		.45	1.20	.80	31		.35		1.20
16		.45	1.50	.80					

MISSOURI RIVER AT CASCADE, MONT.

This station was established July 1, 1902, by W. W. Schlecht. It is located at the highway bridge in the town of Cascade, Mont., about one-fourth of a mile from the railroad. The gage is of the usual wire type, and the scaleboard is graduated to feet and tenths and is fastened to one of the eyebars of the bridge. It is read daily by H. W. Ludwig. The initial point for sounding is on the abutment of the right approach to the bridge. The channel is straight for about 600 feet above the station and 300 feet below. About 300 feet below the station there is an island, on either side of which the river is rapid. There is about 1 foot fall at this point. The right bank is low and liable to overflow. The left bank is high and not liable to overflow. The bed of the stream is rocky near the piers and muddy along the banks. The bridge has two spans. The central pier is protected by an ice and drift breaker, which extends about 125 feet upstream. No bench marks have been established.

The following measurements were made during 1902 by W. W. Schlecht and L. V. Branch:

July 21: Gage height, 5.06 feet; discharge, 5,537 second-feet.
September 9: Gage height, 3.67 feet; discharge, 1,891 second-feet.
November 6: Gage height, 4.18 feet; discharge, 3,131 second-feet.

Daily gage height, in feet, of Missouri River at Cascade, Mont.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.						
1	.....	4.20	3.67	3.90	4.20	[illegible]
2	.....	4.15	3.55	3.95	4.20	[illegible]
3	.....	4.05	3.77	4.00	4.20	[illegible]
4	.....	3.90	3.87	4.05	4.20	[illegible]
5	.....	3.87	3.85	4.07	4.20	[illegible]
6	.....	3.75	3.75	4.05	4.18	[illegible]
7	.....	3.62	3.70	4.00	4.17	.....
8	.....	3.60	3.65	4.00	4.20	.....
9	.....	3.60	3.70	4.00	4.20	.....
10	.....	3.60	3.67	4.05	4.20	.....
11	.....	3.60	3.62	4.05	4.25	.....
12	.....	3.60	3.60	4.10	4.32	.....
13	.....	3.60	3.60	4.10	4.45	.....
14	.....	3.60	3.60	4.15	4.50	.....
15	.....	3.60	3.60	4.10	4.50	.....
16	.....	3.55	5.60	4.10	4.55	.....
17	5.35	3.50	3.65	4.10	4.55	.....
18	5.30	3.45	3.65	4.10	4.60	.....
19	5.22	3.55	3.70	4.10	4.57	.....
20	5.12	3.50	3.70	4.15	4.55	.....
21	5.00	3.72	3.70	4.15	4.50	.....
22	5.00	3.92	3.70	4.15	4.45	.....
23	4.90	3.90	3.70	4.10	4.20	.....
24	4.80	3.90	3.70	4.10	4.50	.....
25	4.70	3.87	3.70	4.10	4.00	.....
26	4.65	3.85	3.65	4.10	4.00	.....
27	4.60	3.85	3.62	4.10	4.00	.....
28	4.50	3.85	3.60	4.18	4.00	.....
29	4.40	3.82	3.65	4.20	4.00	.....
30	4.30	3.75	3.72	4.20	4.00	.....
31	4.30	3.70	.....	4.20	.....	.....

MISSOURI RIVER AT TOWNSEND, MONT.

The gaging station was established in 1891 by the Missouri River Commission, and readings have been made continuously since that time by an observer employed by the Commission. The locality is 2,504 miles above the mouth of the river. The following description of the gage, its location, and bench marks is from Lieut. J. C. Sanford, secretary of the Missouri River Commission:

A standard wire cable gage was erected by the Missouri River Commission October 1, 1891, on a county road bridge, located about 300 feet below the Northern Pacific Railroad bridge across the Missouri River near Townsend, Mont. Its zero is set at an approximate elevation of 3,700 feet above sea level as determined from a primary line of levels, run under the direction of the Commission in 1890, from Three Forks to Fort Benton, Mont., and starting from a bench mark of the Northern Pacific Railroad at Gallatin, Mont. (See Annual Report of Chief of Engineers, 1891.)

Reference bench mark is B. M. 10 (Townsend), described as "located on the right bank of the Missouri River, about one-half mile north of Townsend Railroad station, about one-half mile from river, measured in a perpendicular direction to track, and about three-fourths mile south of railroad bridge over the Missouri

River. It is about 60 feet west of a point on the track, 30 feet north of railroad bridge No. 392, and about 7 feet west of railroad fence. Compass reading to mile-post 1121 is 318°. Marked by stone and pipe; elevation, 3,795.991 feet. This elevation is erroneous, but is the elevation from which the gage is set.

The tabulated records of the Townsend gage are reductions to the St. Louis directrix datum obtained by subtracting 400.063 feet from the daily means of the gage readings. The gage reads from 3,785 to 3,799 feet.

Lieutenant Sanford states that since the establishment of the gage level lines have been completed connecting all of the upper river gages with the datum of the Missouri River Commission. Precise levels have been run up to Sioux City, Iowa, and above that checked Y lines have been run under the direction of Capt. H. F. Hodges, Corps of Engineers, United States Army, and of the Missouri River Commission. The elevations of the zeros of the other Montana gages read during 1890 are as follows:

Elevations of river gages in Montana.

Locality.	Above mouth.	Elevation of gage zero.	Locality.	Above mouth.	Elevation of gage zero.
	Miles.	*Feet.*		*Miles.*	*Feet.*
Great Falls	2,383.3	2,897.165	Toston	2,519.8	3,477.230
Craig	2,415.7	3,028.575	Gallahers Ferry	2,546.4	3,613.069
Stubbs Ferry	2,463.8	3,207.674	Gallatin Ferry	2,546.7	3,614.783

The area drained at this point is approximately 15,000 square miles, comprising, as above stated, the inflow from the Gallatin, the Madison, and the Jefferson rivers. This gage at Townsend is the highest of a series of twenty or more gages maintained permanently by the Missouri River Commission. Descriptions of these gages are given in the annual report of the Missouri River Commission, contained in the Annual Report of the Chief of Engineers, United States Army; that for 1891, on page 3819; for 1892, on page 3271, and for 1893, on page 2316. The distance of this point above Sioux City is 1,703 miles, and above Fort Benton, the next gage below maintained by the Corps of Engineers, 219 miles. In the report of the Chief of Engineers, United States Army, for 1893, page 2320, it is stated that there is under way an "examination of Missouri River from Three Forks to Canyon Ferry, Mont., with a view of determining at what points, if any, use might be made of water power for manufacturing and other purposes without unreasonably impairing the navigability. This part of the river was surveyed and mapped in 1890 under the direction of the Missouri River Commission. For the present work it is proposed to examine the maps of this survey and select such points as seem suitable to personally examine the localities, and by additional field work to get the necessary data for a report."

The gaging station on the upper Missouri River in the vicinity of Craig, referred to in previous reports, was abandoned in June, 1892, owing to the expense of maintenance and the fact that the Missouri River Commission had a gage at Townsend, Mont.

The results are furnished to the Geological Survey by the Corps of Engineers, United States Army.

Discharge measurements of Missouri River at Townsend, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 14	H. B. Waters	88.75	2,840
July 14	do	89.82	6,547
August 28	do	88.52	2,350

GALLATIN RIVER AT LOGAN, MONT.

This station was established on August 24, 1893, by F. H. Newell, at the railroad pump house immediately below the Northern Pacific main line bridge crossing Gallatin River at Logan, Mont. The gage was a vertical rod fastened to the cribwork box sunk in the river for the protection of the inlet pipe of the pump. The bench marks consist of nails driven into the angle of the pier of the bridge facing the gage, these being placed at the elevation of the 7, 8, 9, and 10 foot marks, and designated by corresponding figures. At the bridge itself measurements of volume can not well be made, as the stream is divided into four channels, being very swift in two of these, and obstructed by piles, snags, and sand in the others. Above the bridge, however, is a broad, straight course, where measurements can be made by means of a boat and cable.

On March 10, 1894, the gage rod was washed out, together with the crib to which it was attached, no discharge measurements having been made while it was in place.

On November 16, 1894, a new gage was established by Arthur P. Davis under the northeast corner of the Northern Pacific bridge above mentioned. This gage consisted of timbers partly inclined and partly vertical, the lower inclined portion being graduated from 0.60 foot up to 7.10 feet, and the vertical portion from 7 feet up to 12.10 feet. Bench mark No. 1 is on the head of a bridge spike, in the top of the pile stump to which the lower end of the inclined gage is fastened. Elevation 1.62 feet above zero of gage. Bench mark No. 2 is the head of a bridge spike driven horizontally into the first pier east of the river. It is driven into the north end, and is marked "B. M." Its elevation is 9.32 feet above the zero of the gage. The measurements were made by means of a cable across the river 100 yards above the bridge.

On September 16, 1896, a wire gage was placed in the east span of the railroad bridge and fastened to the guard rail on the upper side. The distance from the outside edge of the pulley to the end of the rod is 1 foot; from the end of the weight to the index marker 18.40 feet. Bench mark 1 is the top of the northeast corner of the iron plate at foot of diagonal end member of truss, east end, upper side,

and is 13.70 feet above datum. Bench mark 2 is a spike in pile stump, described and called "Bench mark No. 1," in the description of the 1894 gage. Discharge measurements are made from the cable across the river 300 feet above the railroad bridge. The section is a good one, the channel being straight for some distance above and below the cable. The bed is gravelly. The observer is James Martin. The following measurements were made in 1902:

Discharge measurements of Gallatin River at Logan, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 15	H. B. Waters	0.91	486
May 3	do	1.30	715
Do	do	1.30	720
May 28	do	4.23	4.018
July 14	do	1.66	986
August 29	do	.56	394

Daily gage height, in feet, of Gallatin River at Logan, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1		(a)	a1.05	1.30		4.40		0.80	0.60	1.10	1.10	1.40
2			1.05	1.30		4.30		.70	.60	1.10	1.10	1.20
3			1.05	1.30		3.75		.60	.60	1.10	1.10	1.20
4	(a)		1.05	1.30	1.30	3.55		.60	.60	1.10	1.10	1.30
5	1.00		1.05	1.30	1.20	3.25		.60	.60	1.10	1.10	1.40
6	1.00		1.05	1.30	1.20	3.35		.50	.60	1.10	1.20	1.30
7	1.00		1.05	1.30	1.30	3.35		.50	.60	1.10	1.10	1.30
8	1.00	(a)	1.04	1.30	1.40	4.15		.50	.60	1.10	1.20	1.30
9	1.00		1.40	1.30	1.60	4.10		.50	.60	1.10	1.20	1.20
10	1.00		1.40	1.30	1.60	4.30		.60	.60	1.10	1.20	1.20
11	a1.00		1.40	1.30	1.80	4.40		.60	.60	1.10	1.30	1.20
12	1.00		1.30	1.30	2.40	4.15		.60	.60	1.10	1.40	1.10
13	1.00		1.30		2.55	4.35		.60	.60	1.10	1.30	1.00
14	1.00		1.30		2.60	4.40	1.70	.60	.50	1.10	1.20	1.20
15	1.00	(a)	1.30		3.35	2.95	1.50	.70	.30	1.10	1.20	1.40
16	1.00	1.10	1.30		3.45	2.55	1.40	.70	.20	1.10	1.20	1.60
17	1.00	1.10	1.30		3.50	2.50	1.30	.70	.30	1.10	1.20	2.50
18	1.00	1.10	1.30		3.50	2.45	1.30	.80	.30	1.10	1.20	2.45
19		1.10	1.30		3.40	2.50	1.30	.80	.20	1.10	1.30	2.85
20		1.10	1.30		3.40	2.30	1.20	.70	.20	1.10	1.20	2.90
21		1.10	1.30		3.35	2.10	1.10	.70	.20	1.10	1.10	3.10
22		1.10	1.30		3.30	2.30	1.10	.70	.20	1.10	1.20	3.40
23	(a)	1.05	1.30		3.35	2.40	1.00	.70	.20	1.10	1.30	3.60
24		1.05	1.30		3.30	2.40	.90	.70	.20	1.10	1.40	3.35
25		1.05	1.30		3.10	2.30	.80	.60	.10	1.10	1.40	3.30
26		1.05	1.30		3.10	2.44	.80	.70	.10	1.10	1.40	3.30
27		1.05	1.30		3.45	2.10	.80	.60	.10	1.10	1.40	2.40
28		1.05	1.30		3.80	2.20	.90	.60	1.10	1.10	1.40	2.10
29			1.30		3.90		.80	.60	1.10	1.10	1.40	2.10
30			1.30		4.05		.80	.60	1.10	1.10	1.40	2.60
31			1.30		4.35		.70	.60		1.10		2.80

a Frozen at gage.

Rating table for Gallatin River at Logan, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	356	1.4	780	2.6	1,965	3.8	3,520
.4	370	1.6	940	2.8	2,200	4.0	3,830
.6	400	1.8	1,120	3.0	2,440	4.2	4,125
.8	450	2.0	1,315	3.2	2,700	4.4	4,430
1.0	530	2.2	1,520	3.4	2,960		
1.2	650	2.4	1,735	3.6	3,240		

Estimated monthly discharge of Gallatin River at Logan, Mont.

[Drainage area, 1,805 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January 5 to 18			530	14,717	0.29	0.1
February 16 to 28			576	14,856	.32	.1
March	780	560	678	41,693	.38	.4
April 1 to 12			710	16,899	.39	.1
May 4 to 31			2,328	129,291	1.29	1.3
June 1 to 28			2,775	154,136	1.54	1.6
July 14 to 31			599	21,398	.33	.2
August	450	382	410	25,206	.23	.2
September	590	356	399	23,742	.22	.2
October	590	590	590	36,278	.33	.3
November	780	590	679	40,383	.38	.4
December	3,240	530	1,465	90,079	.81	.9

WEST GALLATIN RIVER NEAR SALESVILLE, MONT.

The Salesville station, which has been maintained for a number of years, was established near Williams's ranch, about 16 miles south west of Bozeman and near a highway bridge crossing the stream about 5 miles south of Salesville. A gage rod was erected in July 1895, and observations were begun on August 1 by Ira T. Williams, a ranchman living about 600 feet away. The gage is spiked to a tree and is not liable to be washed out. The bench mark consists of a 6-inch spike driven in the top of a stump 5 feet north of the gage post. It is 6.71 feet above the zero of the gage, as lowered 5 feet

om the original position. A second bench mark consists of a 6-inch pike driven into the east bridge abutment. This is 9.26 feet above ne zero of the gage. The initial point for soundings is on the right ank. In flood the water flows behind the bridge abutments on the ight bank, but at other times is confined within the channel. The ed of the stream is composed of bowlders and is not liable to change. The velocity is great, rendering discharge measurements somewhat difficult. The channel is nearly straight, with slight curves both above and below. Two canals are taken out above this station, the West Gallatin Company carrying about 125 second-feet between July 1 and September 15, and the Kleinschmidt carrying about 50 second-feet between July 1 and August 15. In September, 1896, a wire gage was placed on the bridge, the pulley being fastened to the end of the rod opposite the 0.15-foot mark. The distance of the end of the weight to the index marker is 15.50 feet. The two gages were made to read the same.

The bench mark for the wire gage is the head of the southwest bolt in the rim of the southeast cylindrical pier. Its elevation is 13.70 feet above datum. The observer is Ira T. Williams, Salesville, Mont.

Discharge measurements of West Gallatin River near Salesville, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 28	H. B. Waters	2.83	373
June 3	A. P. Stover	5.30	2,629
Do	do	5.30	2,606
June 9	do	6.12	4,361
June 14	do	6.30	4,768
June 24	do	5.05	2,778
Do	do	5.05	2,779
July 10	do	4.25	1,074
July 17	H. B. Waters	4.14	1,348
August 13	A. P. Stover	3.30	627
September 4	H. B. Waters	2.80	433

Daily gage height, in feet, of West Gallatin River near Salesville, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De
1902.												
1	2.80	2.80	2.70	2.70	3.00	6.40	4.50	3.60	3.00	2.90	2.90	2
2	2.80	2.80	2.70	2.70	3.00	5.55	4.00	3.50	2.95	2.90	2.90	2
3	2.80	2.90	2.70	2.70	2.90	5.30	4.65	3.40	2.90	2.90	2.90	2
4	2.80	3.00	2.70	2.70	2.90	5.20	4.50	3.40	2.90	2.90	2.90	2
5	2.80	3.25	2.70	2.70	2.90	5.20	4.40	3.40	2.80	2.90	2.90	2
6	2.80	3.30	2.70	2.70	3.00	5.20	4.40	3.30	2.80	2.90	2.90	2
7	2.80	3.30	2.70	2.70	3.20	5.50	4.30	3.30	2.80	2.90	2.90	2
8	2.80	3.20	2.70	2.70	3.30	6.35	4.25	3.30	2.70	2.90	2.90	2
9	2.80	3.20	2.70	2.70	3.60	6.50	4.20	3.30	2.70	2.90	2.90	2
10	2.80	3.20	2.70	2.70	3.87	6.40	4.20	3.20	2.70	2.90	2.90	2
11	2.80	3.00	2.70	2.70	4.00	6.40	4.20	3.20	2.70	2.90	2.90	2
12	2.80	3.00	2.70	2.70	4.15	6.10	4.20	3.10	2.70	2.90	2.90	2
13	2.80	3.00	2.70	2.80	4.45	6.10	4.25	3.20	2.70	2.90	2.90	2
14	2.80	2.90	2.70	2.80	4.75	6.05	4.25	3.20	2.70	2.90	2.90	2
15	2.80	2.80	2.70	2.70	5.25	5.75	4.30	3.20	2.90	2.90	2.90	2
16	2.80	2.80	2.70	2.70	4.90	5.20	4.30	3.20	2.80	2.90	2.90	2
17	2.80	2.80	2.70	2.70	4.75	5.10	4.30	3.20	2.80	2.90	2.90	
18	2.80	2.70	2.70	2.70	4.55	5.10	3.80	3.10	2.90	2.90	2.90	
19	2.70	2.70	2.70	2.70	4.40	5.00	4.10	3.10	2.90	2.90	2.90	
20	2.70	2.70	2.70	3.00	4.15	4.80	4.10	3.10	2.90	2.90	2.90	
21	2.70	2.70	2.70	3.00	3.95	4.80	3.90	3.10	2.90	2.90	2.90	
22	2.70	2.70	2.70	2.90	4.00	4.85	3.90	3.10	2.80	2.90	2.90	
23	2.70	2.70	2.70	2.90	4.20	5.00	3.90	3.10	2.90	2.90	2.90	
24	2.70	2.70	2.78	2.90	4.45	5.05	3.90	3.00	2.90	2.90	2.90	
25	2.70	2.70	2.75	2.90	4.45	5.00	3.90	3.00	2.90	2.90	2.80	
26	2.70	2.70	2.78	2.90	4.80	5.10	3.90	3.00	2.90	2.90	2.70	
27	2.70	2.70	2.73	2.90	5.15	4.90	3.90	3.00	2.90	2.90	2.60	
28	2.80	2.70	2.75	2.90	5.95	4.80	3.90	3.00	2.90	2.90	2.70	
29	2.80	.....	2.75	2.90	6.25	4.50	3.70	3.00	2.90	2.90	2.90	
30	2.80	.....	2.70	2.90	6.55	4.50	3.70	3.00	2.90	2.90	2.90	
31	2.80	.....	2.70	.....	6.65	.....	3.70	3.00	.....	2.90	.....	

Rating table for West Gallatin River near Salesville, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharg
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
2.6	300	3.8	930	5.0	2,285	6.2	4,550
2.8	400	4.0	1,060	5.2	2,605	6.4	5,000
3.0	500	4.2	1,215	5.4	2,950	6.6	5,450
3.2	600	4.4	1,415	5.6	3,310		
3.4	700	4.6	1,665	5.8	3,690		
3.6	810	4.8	1,960	6.0	4,100		

Estimated monthly discharge of West Gallatin River near Salesville, Mont.

[Drainage area, 860 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	400	360	388	23,881	0.45	0.52
February	650	360	449	24,962	.52	.54
March	400	360	365	22,413	.42	.48
April	500	360	399	23,742	.46	.51
May	5,565	450	1,697	104,370	1.97	2.27
June	5,225	1,530	3,025	180,030	3.52	3.93
July	1,735	870	1,192	73,269	1.39	1.60
August	810	500	591	36,327	.69	.80
September	500	360	422	25,081	.49	.55
October	450	450	450	27,669	.52	.60
November	450	300	437	26,023	.51	.57
December	450	270	407	25,031	.47	.54
The year	5,565	270	818	592,798	.95	12.91

MIDDLE CREEK NEAR BOZEMAN, MONT.

The station, established on August 3, 1895, is located 9 miles south of Bozeman and one-eighth of a mile above the old sawmill dam in the creek canyon. Discharge measurements are made from a wire cable placed across the stream in 1898. The gage is about 200 feet below the cable, and consists of a horizontal frame supporting a wire gage. Bench mark No. 1 consists of a spike driven horizontally into a stump 5 feet high about 80 feet east of the gage rod. The middle of this spike is at an elevation of 7.03 feet above gage datum. Bench mark No. 2 consists of an 8-inch bridge spike driven horizontally into a charred stump about 25 feet northeast of the gage, with an elevation of 3.58 feet. Bench mark No. 3 consists of a large rock 93 feet east of the gage, marked "B. M." in black paint, and is 4.84 feet above gage datum. The initial point for sounding is on the left bank. The water moves swiftly on one side; the left bank is low and liable to overflow. The bed of the stream is of gravel and is liable to change. Gage heights were not taken in 1897 and 1901, owing to the impossibility of securing an observer at moderate expense.

A new gage and three new bench marks were established at this station on May 8, 1902. Bench mark No. 1 is the top of a bowlder 56 feet southeast of the deadman of the east end of the cable. It is marked in red paint B. M., U. S. G. S., 8.41; elevation 8.41 feet above

the zero of the gage. Bench mark No. 2 is the top of a bowlder feet southeast of the deadman, marked in red paint B. M., U. S. G. 9.26; elevation 9.26 feet above zero of the gage. Bench mark No is a large bowlder on the hillside 150 feet northeast of the deadm marked B. M., U. S. G. S., 20.43; elevation 20.43 above the zero the gage. The relation of the gage zeros has not been determined

Discharge measurements of Middle Creek near Bozeman, Mont.

Date.	Hydrographer.	Gage height.	Dischar
1902.		*Feet.*	*Second-*
May 7	J. S. Baker	1.02	
Do	do	1.08	
Do	do	1.12	
June 4	A. P. Stover	1.45	
Do	do	1.45	
June 19	do	1.40	
July 9	do	1.25	
July 17	H. B. Waters	1.30	
August 12	A. P. Stover	1.00	
September 11	H. B. Waters	.81	

Daily gage height, in feet, of Middle Creek near Bozeman, Mont.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	O
1902.							1902.						
1			1.50	1.10	0.90	0.85	17	1.50	1.60	1.35	1.00	0.80	
2		1.60	1.50	1.10	.90	.85	18	1.40	1.50	1.30	1.00	.80	
3		1.50	1.50		.85	.85	19	1.30	1.50	1.25	.90	.80	
4		1.40	1.45	1.10	.85		20	1.30	1.45		.90	.80	
5		1.40	1.45	1.50	.85		21	1.30	1.50	1.25	.90		
6		1.40		1.50	.80		22	1.30		1.25	.90	.80	
7		1.50	1.40	1.50			23	1.30	1.60	1.25	.90	.80	
8			1.35	1.50	.80		24	1.40	1.60	1.25		.80	
9		1.60	1.35	1.00	.80		25	1.40	1.65	1.25	.90	.85	
10		1.80	1.35		.80		26	1.50	1.60	1.20	.90	.85	
11		1.90	1.35	1.00	.80		27	1.60	1.60		.90	.85	
12		1.80	1.35	1.00	.80		28	1.70	1.50	1.15	.90		
13		1.70		1.00	.80		29	1.70		1.10	.90	.85	
14	(a)	1.80	1.30	1.00			30	1.70	1.50	1.10	.90	.85	
15	1.60		1.30	1.00	.80		31	1.80		1.10			
16	1.50	1.70	1.35	1.00	.80								

a Observer did not read gage on Sundays.

Rating table for Middle Creek near Bozeman, Mont., for 1902.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
49	1.1	72	1.4	136	1.7	271
53	1.2	88	1.5	181	1.8	316
60	1.3	107	1.6	226	1.9	361

imated monthly discharge of Middle Creek near Bozeman, Mont.[a]

[Drainage area, 55 square miles.]

onth.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
98.						
o 30			195	5,018	3.55	1.72
	466	118	270	16,610	4.91	5.66
	956	153	429	25,521	7.80	8.70
	298	88	172	10,586	3.13	3.61
	77	57	65	3,989	1.18	1.36
r	57	48	53	3,178	.96	1.07
to 21			52	2,255	.95	.78
99.						
31			164	8,150	2.98	2.77
	760	232	504	29,982	9.16	10.22
	564	153	334	20,559	6.07	7.00
	153	66	104	6,383	1.89	2.18
r	77	48	57	3,414	1.04	1.16
	66	48	49	2,987	.89	1.03
02.						
31			180	6,069	3.27	2.07
	361	122	221	13,150	4.02	4.49
	181	72	116	7,133	2.11	2.43
	181	53	74	4,564	1.35	1.56
r	53	49	50	2,975	.91	1.02

[a] The results for 1898 and 1899, as previously published, were in error.

MADISON RIVER NEAR REDBLUFF, MONT.

This station is located at the ranch of the observer, Mrs. S. A. Black, 4 miles below the Redbluff iron county bridge over the Madison, and about 1½ miles below the mouth of Cherry Creek. It is also about 3 miles below the location of the old Redbluff station, described in Bulletin No. 131, on page 18. It was established May 2, 1897, at which time the one at Threeforks was discontinued. The vertical gage is fastened to a post set firmly into the bed of the river, and braced with cross-pieces from the bank. Discharge measurements are made from the iron bridge above. Cherry Creek is measured at the same time, as it enters between the gage and the bridge. The initial point for soundings is at the left abutment of the bridge. The banks are high and do not overflow. The bed of the stream is rocky and the current is quite swift. The following are the discharge measurements made during 1902 by H. B. Waters:

April 29: Gage height, 1.40 feet; discharge, 1,485 second-feet.
July 18: Gage height, 1.74 feet; discharge, 2,403 second-feet.
July 18: Gage height, 1.74 feet; discharge, 2,426 second-feet.
September 4: Gage height, 1.31 feet; discharge, 1,424 second-feet.

Daily gage height, in feet, of Madison River near Redbluff, Mont.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
1	(a)	1.00	1.40	3.00	1.95	1.40	1.30	1.30	1.30
2		1.00	1.40	3.00	2.00	1.40	1.30	1.30	1.30
3	(a)	1.20	1.40	2.75	2.00	1.40	1.30	1.30	1.30
4		1.20	1.40	2.51	2.10	1.35	1.30	1.30	1.30
5		1.20	1.40	2.50	2.00	1.30	1.30	1.30	1.30
6		1.30	1.43	2.45	2.00	1.30	1.30	1.30	1.30
7		1.30	1.45	2.35	1.95	1.30	1.30	1.30	1.30
8		1.30	1.50	2.35	1.90	1.30	1.30	1.30	1.30
9		1.30	1.50	2.55	1.80	1.30	1.30	1.30	(a)
10		1.30	1.50	2.85	1.80	1.30	1.30	1.30	
11	(a)	1.30	1.60	2.95	1.80	1.30	1.30	1.30	
12		1.30	1.70	2.95	1.80	1.30	1.30	1.30	
13		1.30	1.80	2.90	1.80	1.30	1.30	1.30	
14		1.30	1.90	2.90	1.80	1.30	1.30	1.30	
15		1.30	2.05	2.80	1.80	1.30	1.30	1.30	
16		1.30	2.20	2.60	1.80	1.30	1.30	1.30	
17	(a)	1.30	2.20	2.35	1.75	1.30	1.30	1.30	
18		1.35	2.20	2.25	1.70	1.30	1.30	1.30	
19		1.35	2.17	2.10	1.70	1.30	1.30	1.30	
20		1.40	2.10	2.20	1.70	1.30	1.30	1.30	
21		1.40	2.01	1.90	1.70	1.30	1.30	1.30	
22	(a)	1.40	1.90	1.90	1.60	1.30	1.30	1.30	
23	1.00	1.40	1.90	1.95	1.55	1.30	1.30	1.30	
24	1.00	1.40	1.90	2.00	1.50	1.20	1.30	1.30	
25	1.00	1.50	2.00	2.00	1.50	1.20	1.30	1.30	
26	1.00	1.50	2.15	2.10	1.50	1.20	1.30	1.30	
27	1.00	1.50	2.40	2.00	1.50	1.20	1.30	1.30	
28	1.00	1.50	2.60	1.90	1.50	1.20	1.30	1.30	
29	1.00	1.50	2.70	1.90	1.45	1.20	1.30	1.30	
30	1.00	1.40	2.85	1.90	1.40	1.20	1.30	1.30	
31	1.00		3.00		1.40	1.30		1.30	

[a] *River frozen at gage* January 1 to March 23, and November 9 to December 31.

Rating table for Madison River near Redbluff, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	910	1.6	2,075	2.2	3,745	2.8	5,540
1.1	1,025	1.7	2,325	2.3	4,035	2.9	5,840
1.2	1,175	1.8	2,600	2.4	4,345	3.0	6,140
1.3	1,360	1.9	2,880	2.5	4,655	3.1	6,440
1.4	1,570	2.0	3,160	2.6	4,935		
1.5	1,815	2.1	3,450	2.7	5,230		

Estimated monthly discharge of Madison River near Redbluff, Mont.

[Drainage area, 2,085 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
March 23 to 31	.....	.....	910	16,245	0.44	0.15
April	2,075	910	1,436	85,448	.69	.77
May	6,140	1,570	3,001	184,524	1.44	1.66
June	6,440	2,880	4,336	258,010	2.08	2.32
July	3,450	1,570	2,435	149,722	1.17	1.35
August	1,570	1,175	1,361	83,685	.65	.75
September	1,360	1,360	1,360	80,926	.65	.73
October	1,360	1,360	1,360	83,623	.65	.75
November 1 to 8	.....	.....	1,360	21,580	.65	.19

JEFFERSON RIVER AT SAPPINGTON, MONT.

The station on this river is located at Sappington, 7 miles above Willow Creek, and was established by Arthur P. Davis November 13, 1894. The wire gage is fastened to the guard rail on the upper side of the Northern Pacific Railway bridge, 1 mile north of the railroad station. Bench mark No. 1 consists of a 6-inch wire nail driven horizontally in the east side of the blocking which forms the south abutment of the railroad bridge and is 6.90 feet above gage datum. Bench mark No. 2 is a 6-inch wire nail in a telegraph pole, about 30 feet south and east of the south abutment of the bridge, and is at an elevation of 7 feet on the gage. Bench mark No. 3 is the head of the northwest bolt fastening the switch standard to the cross-tie, 30 feet east of the bridge. Its elevation is 15.67 feet. On November 3, 1897, the rod was lowered eight-tenths of a foot, the subsequent years being adjusted to the new datum, but the balance of 1897 was corrected to agree with old datum. Discharge measurements are made

from a cable and car installed a short distance above the bridge. T
following measurements were made during 1902 by H. B. Waters.

April 16: Gage height, 2.10 feet; discharge, 1,18 second-feet.
May 27: Gage height, 4.90 feet; discharge, 5,940 second-feet.
July 15: Gage height, 2.99 feet; discharge, 2,534 second-feet.
August 1. Gage height, 2.03 feet; discharge, 1,137 second-feet.
August 29: Gage height, 1.67 feet; discharge, 663 second-feet.

Daily gage height, in feet, of Jefferson River at Sappington, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1	(a)	3.20		1.80	3.20	6.50	3.20	2.15	1.60	1.80	2.10	2
2				1.85	3.20	6.50	3.20	2.00	1.60	1.80	2.10	2
3				2.00	3.20	6.30	3.20	2.00	1.40	1.80	2.10	2
4				2.00	3.20	5.90	3.55	1.90	1.55	1.80	2.15	2
5	b 3.50			2.10	3.10	5.35	3.90	1.80	1.60	1.85	2.20	2
6				2.20	3.00	5.10	4.20	1.80	1.60	1.90	2.20	2
7				2.10	2.90	4.70	4.10	1.45	1.65	1.90	2.20	2
8		3.30		2.20	2.90	4.55	3.85	1.35	1.70	1.90	2.20	2
9				2.10	3.25	4.60	3.60	1.45	1.70	1.90	2.20	2
10				2.20	3.55	4.60	3.55	1.60	1.70	1.90	2.20	2
11	b 3.20			2.25	3.85	4.70	3.30	1.50	1.65	1.90	2.25	2
12				2.10	4.05	5.10	3.20	1.50	1.60	1.90	2.30	2
13				2.00	4.10	5.10	3.15	1.65	1.60	2.00	2.30	
14				2.20	4.30	5.10	3.00	1.70	1.60	2.00	2.35	
15		3.40		1.95	4.65	5.10	2.95	1.70	1.60	2.00	2.40	
16				2.00	5.20	4.95	2.75	1.70	1.60	2.00	2.40	
17				2.10	5.50	4.70	2.70	1.70	1.60	2.00	2.40	
18				2.10	5.40	4.10	2.65	1.80	1.65	2.00	2.40	
19				2.20	5.10	3.80	2.65	1.80	1.70	2.00	2.50	
20				2.40	5.00	3.55	2.80	1.90	1.70	2.00	2.50	
21				3.20	5.00	3.45	2.70	1.85	1.70	2.00	2.45	
22		3.40		3.55	4.80	3.30	2.65	1.80	1.70	2.00	2.40	
23				3.60	4.60	3.20	2.50	1.70	1.70	2.00	2.30	
24				3.60	4.75	3.20	2.50	1.70	1.70	2.00	2.30	
25	3.40			3.60	4.80	3.20	2.40	1.70	1.70	2.10	2.30	
26				3.35	4.80	3.15	2.35	1.70	1.70	2.10	2.30	
27				3.30	4.85	3.10	2.20	1.70	1.75	2.10	2.30	
28				3.30	5.15	3.10	2.20	1.70	1.80	2.10	2.30	
29				3.30	5.60	3.10	2.20	1.70	1.80	2.10	2.30	
30			2.00	3.20	6.25	3.20	2.10	1.60	1.80	2.10	2.30	
31			1.90		6.60		2.10	1.60		2.10		

a Weekly observations during January, February, and March. b Ice at gage.

Rating table for Jefferson River at Sappington, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharg
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
1.4	510	2.8	2,230	4.2	4,640	5.6	7,305
1.6	685	3.0	2,550	4.4	5,000	5.8	7,695
1.8	875	3.2	2,870	4.6	5,365	6.0	8,085
2.0	1,090	3.4	3,205	4.8	5,750	6.2	8,475
2.2	1,335	3.6	3,550	5.0	6,140	6.4	8,865
2.4	1,610	3.8	3,905	5.2	6,525	6.6	9,255
2.6	1,915	4.0	4,270	5.4	6,915		

stimated monthly discharge of Jefferson River at Sappington, Mont.

[Drainage area, 8,984 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
.....	3,550	875	1,875	111,570	0.21	0.23
.....	9,255	2,390	5,028	309,160	.56	.65
.....	9,060	2,710	5,081	302,340	.57	.64
.....	4,640	1,210	2,502	153,842	.28	.32
t	1,150	485	801	49,252	.09	.10
ıber	875	645	739	43,974	.08	.09
r	1,210	875	1,059	65,115	.12	.14
ıber	1,755	1,210	1,460	86,876	.16	.18
ber	1,755	1,470	1,630	100,225	.18	.21

Miscellaneous measurements in Missouri River drainage basin.

ade by B. E. Forbes, J. C. Stevens, Adna Dobson, A. B. Crane, and H. B. Waters.]

NEBRASKA.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
; 9	Long Pine Creek	Long Pine	49.7
22	Minnechaduza Creek	Valentine	38.1
1	do	Sec. 29, T. 35, R. 30 W	14.9
.....	do	Sec. 2, T. 34, R. 30 W	17.3
.....	do	Sec. 8, T. 34, R. 29 W	26.0
.....	do	Sec. 30, T. 34, R. 38 W	33.8
2	do	Valentine	38.3
.....	do	do	23.1
.....	do	do	27.4
)	do	do	22.7
; 20	do	do	23.8
22	Niobrara River	Fort Niobrara	1,226
2	do	do	877
.....	do	W. line sec. 26, T. 29, R. 46 W.	25.4
5	do	Fort Niobrara	588
.....	do	do	714
)	do	do	705
.....	White River	Sec. 34, T. 32, R. 52 W	64.9
t 20	do	Sec. 25, T. 32, R. 52 W ...	10.4
ıber 8	Big Sioux	Sioux Falls, S. Dak	48.4

Rating table for Gallatin River at Logan, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	356	1.4	780	2.6	1,965	3.8	3,520
.4	370	1.6	940	2.8	2,200	4.0	3,830
.6	400	1.8	1,120	3.0	2,440	4.2	4,125
.8	450	2.0	1,315	3.2	2,700	4.4	4,430
1.0	530	2.2	1,520	3.4	2,960		
1.2	650	2.4	1,735	3.6	3,240		

Estimated monthly discharge of Gallatin River at Logan, Mont.

[Drainage area, 1,805 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January 5 to 18	.....	.....	530	14,717	0.29	0.15
February 16 to 28	.....	.....	576	14,856	.32	.15
March	780	560	678	41,693	.38	.44
April 1 to 12	.....	.....	710	16,899	.39	.18
May 4 to 31	.....	.....	2,328	129,291	1.29	1.34
June 1 to 28	.....	.....	2,775	154,136	1.54	1.60
July 14 to 31	.....	.....	599	21,398	.33	.22
August	450	382	410	25,206	.23	.27
September	590	356	399	23,742	.22	.25
October	590	590	590	36,278	.33	.38
November	780	590	679	40,383	.38	.42
December	3,240	530	1,465	90,079	.81	.93

WEST GALLATIN RIVER NEAR SALESVILLE, MONT.

The Salesville station, which has been maintained for a number of years, was established near Williams's ranch, about 16 miles southwest of Bozeman and near a highway bridge crossing the stream about 5 miles south of Salesville. A gage rod was erected in July, 1895, and observations were begun on August 1 by Ira T. Williams, a ranchman living about 600 feet away. The gage is spiked to a tree and is not liable to be washed out. The bench mark consists of a 6-inch spike driven in the top of a stump 5 feet north of the gage post. It is 6.71 feet above the zero of the gage, as lowered 5 feet

from the original position. A second bench mark consists of a 6-inch spike driven into the east bridge abutment. This is 9.26 feet above the zero of the gage. The initial point for soundings is on the right bank. In flood the water flows behind the bridge abutments on the right bank, but at other times is confined within the channel. The bed of the stream is composed of bowlders and is not liable to change. The velocity is great, rendering discharge measurements somewhat difficult. The channel is nearly straight, with slight curves both above and below. Two canals are taken out above this station, the West Gallatin Company carrying about 125 second-feet between July 1 and September 15, and the Kleinschmidt carrying about 50 second-feet between July 1 and August 15. In September, 1896, a wire gage was placed on the bridge, the pulley being fastened to the end of the rod opposite the 0.15-foot mark. The distance of the end of the weight to the index marker is 15.50 feet. The two gages were made to read the same.

The bench mark for the wire gage is the head of the southwest bolt in the rim of the southeast cylindrical pier. Its elevation is 13.70 feet above datum. The observer is Ira T. Williams, Salesville, Mont.

Discharge measurements of West Gallatin River near Salesville, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 28	H. B. Waters	2.83	373
June 3	A. P. Stover	5.30	2,629
Do	do	5.30	2,606
June 9	do	6.12	4,361
June 14	do	6.30	4,768
June 24	do	5.05	2,778
Do	do	5.05	2,779
July 10	do	4.25	1,074
July 17	H. B. Waters	4.14	1,348
August 13	A. P. Stover	3.30	627
September 4	H. B. Waters	2.80	433

Daily gage height, in feet, of Elkhorn River near Arlington, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.										
1	.....	2.24	3.20	1.90	1.80	4.95	3.47	4.20	2.88	2.01
2	.....	2.39	3.23	1.88	1.99	4.15	3.12	5.15	2.86	2.10
3	.....	2.51	3.30	1.82	2.20	3.37	2.80	5.07	2.76	[illegible]
4	.....	2.73	3.12	1.72	2.85	3.00	2.64	4.80	2.75	.....
5	.....	2.89	2.71	1.82	3.57	2.75	2.52	4.73	2.72	.....
6	.....	2.83	2.44	1.88	5.80	2.56	2.40	4.60	2.67	.....
7	.....	2.75	2.31	1.75	6.17	2.35	2.24	4.39	2.63	.....
8	.....	2.67	2.23	1.74	5.90	2.21	2.20	4.26	2.58	.....
9	(a)	2.62	2.15	1.99	8.16	2.14	2.17	4.17	2.60	.....
10	3.74	2.50	2.14	2.85	9.10	2.00	2.00	4.06	2.58	.....
11	3.34	2.39	2.08	2.76	8.78	1.95	1.97	4.01	2.56	.....
12	3.17	2.32	2.00	2.60	7.65	1.82	1.94	4.54	2.62	.....
13	3.19	2.21	2.01	2.31	7.66	1.88	1.90	5.14	2.87	.....
14	3.36	2.12	2.02	2.14	7.41	1.81	1.80	5.10	3.30	.....
15	3.37	2.13	1.98	2.10	6.10	2.25	1.76	4.71	3.16	.....
16	3.02	2.12	1.88	1.93	5.85	4.97	1.72	4.28	2.88	.....
17	3.83	2.07	1.87	1.82	5.52	5.50	1.68	4.02	2.76	.....
18	(a)	1.98	1.82	1.91	6.11	4.29	1.61	3.86	2.64	.....
19	(a)	1.96	1.77	2.27	7.11	3.59	1.55	3.72	2.58	.....
20	2.25	1.91	1.75	2.44	7.15	3.03	1.54	3.65	2.55	.....
21	2.32	1.84	1.80	2.15	6.92	2.70	2.06	3.49	2.47	.....
22	2.71	1.80	1.85	1.92	6.50	3.80	2.60	3.42	2.50	.....
23	2.57	1.77	1.93	1.81	5.69	3.44	3.25	3.39	2.47	.....
24	2.42	1.79	1.98	1.75	4.71	3.90	3.59	3.29	2.46	.....
25	2.35	1.75	2.00	1.72	4.06	4.18	3.58	3.22	2.36	.....
26	2.36	1.82	1.95	1.61	4.30	4.57	3.40	3.16	2.32	.....
27	2.28	1.92	1.89	1.60	4.22	5.18	3.45	3.06	2.28	.....
28	2.22	1.95	1.92	1.58	3.86	5.23	3.57	2.96	2.26	.....
29	2.23	2.11	1.90	1.70	3.51	5.06	3.46	2.95	2.24	.....
30	2.21	2.65	1.94	1.74	3.12	5.57	3.92	2.91	2.14	.....
31	2.18	.....	1.90	.....	3.66	3.90	.....	2.82	.....	.....

[a] Operations discontinued from January 1 to March 10, and from December 3 to 31, on account of ice.

Rating table for Elkhorn River near Arlington, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.4	238	2.0	740	3.6	1,706	5.2	3,398
.6	276	2.2	833	3.8	1,882	5.4	3,656
.8	322	2.4	932	4.0	2,067	5.6	3,925
1.0	375	2.6	1,037	4.2	2,263	5.8	4,203
1.2	435	2.8	1,149	4.4	2,469	6.0	4,494
1.4	501	3.0	1,268	4.6	2,686	6.2	4,797
1.6	574	3.2	1,393	4.8	2,913		
1.8	654	3.4	1,542	5.0	3,150		

[a] This table was applied indirectly according to the method outlined on p. 323 of Nineteenth Ann. Rept., U. S. Geol. Surv., pt. 4.

Estimated monthly discharge of the Elkhorn River near Arlington, Nebr.

[Drainage area, 5,980 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
March, 18 days			1,251	44,664	0.21	0.14
April	1,342	731	974	57,950	.16	.18
May	1,640	718	931	57,240	.16	.18
June	1,220	465	781	46,465	.13	.14
July	9,568	585	3,633	223,350	.61	.69
August	3,114	471	1,453	89,341	.29	.33
September	1,846	530	1,001	59,560	.17	.19
October	3,199	1,161	2,034	125,050	.34	.39
November	1,463	804	1,051	62,530	.18	.19

ELKHORN RIVER NEAR NORFOLK, NEBR.

The gaging station established July 16, 1896, is located about 2 miles south of Norfolk, Nebr., near the line of Thirteenth street extended. The gage is on the left bank of the river. It consists of an inclined oak piece, 2 by 4 inches, 12 feet long, resting on beveled blocks which rest in turn on horizontally bedded cross-ties. All are firmly fastened together by lag screws. The zero of the gage is 8.21 feet below a small spike driven horizontally into a tree near the root, about 20 feet back, and downstream from the gage. Also, the zero of the gage is 3.96 feet below the head of a lag screw which is placed vertically in the horizontal trunk of a large living willow tree which overhangs the stream about 15 feet below the gage. Bench mark 3 is a standard 4-foot iron pipe of the United States Geological Survey, located 35 feet west and 7 feet north of the top of the gage, and 15.5 feet west of the ash tree on which is bench mark 1. Its elevation is 10.70 feet above the zero of the gage. The observer is Harold Taft, a farmer boy, whose home is about 300 yards from the gage. The river bed at the station is composed of sand and mud.

Discharge measurements of Elkhorn River near Norfolk, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902		*Feet.*	*Second-feet.*
March 21	J. C. Stevens	2.39	570
April 13	do	2.22	534
May 12	do	2.16	483
June 16	do	2.54	551
July 3	do	4.36	1,376
July 26	do	2.45	475
August 22	do	1.78	296
September 29	do	5.65	2,497
November 14	do	2.34	502

Daily gage height, in feet, of Elkhorn River near Norfolk, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
1		2.95	2.55	2.50	1.90	1.90	2.35	5.92	2.88
2		3.25	2.60	2.35	3.11	1.90	2.70	5.76	2.71
3		3.45	2.60	2.20	4.48	1.85	2.50	5.52	2.69
4		3.20	2.55	2.10	4.00	1.85	2.40	5.35	2.65
5		3.20	2.55	2.95	3.55	1.83	2.10	4.73	2.65
6		2.97	2.50	3.07	3.05	1.81	1.90	4.60	2.59
7		2.90	2.50	2.50	2.90	1.80	1.95	4.39	2.58
8		2.85	2.45	2.55	2.72	1.79	1.97	4.26	2.58
9	(a)	2.80	2.40	2.50	2.80	1.77	1.95	4.17	2.47
10	2.55	2.70	2.30	2.40	2.85	1.75	1.99	4.06	2.47
11	2.60	2.50	2.25	2.35	2.85	1.75	2.00	4.01	2.43
12	2.62	2.32	2.20	2.20	2.90	1.73	2.01	4.26	2.30
13	2.75	2.20	2.20	2.10	2.90	1.70	2.00	4.10	2.21
14	2.72	2.15	2.15	2.40	3.40	1.68	1.98	3.88	2.10
15	2.72	2.15	2.10	2.40	4.00	1.65	1.93	3.66	2.15
16	(a)	2.12	2.15	2.70	3.85	1.70	1.90	3.41	2.03
17	(a)	2.13	2.20	2.80	3.55	1.70	1.85	3.01	1.99
18	(a)	2.15	2.30	2.75	3.85	1.73	1.85	2.97	1.97
19	(a)	2.13	2.60	2.70	3.00	1.75	1.84	3.72	1.97
20	2.65	2.10	2.80	2.61	3.40	1.75	2.00	3.65	2.03
21	2.52	2.15	2.85	2.50	3.25	1.78	2.35	3.49	2.03
22	2.45	2.10	2.80	2.30	3.05	1.80	2.45	3.42	2.09
23	2.42	2.10	2.75	2.22	2.90	1.85	2.37	3.39	2.13
24	2.38	2.01	2.75	2.12	2.85	2.00	2.65	3.29	a 1.12
25	2.40	2.00	2.70	1.95	2.60	2.63	2.83	3.22	a 1.22
26	2.40	2.20	2.60	1.85	2.49	2.78	3.10	3.16	a 1.26
27	2.40	2.35	2.61	1.82	2.40	2.90	3.47	3.06	.....
28	2.45	2.35	2.61	1.80	2.00	3.00	4.89	2.96	.....
29	2.38	2.45	2.60	1.75	2.19	2.60	5.69	2.95	.....
30	2.35	2.50	2.55	1.75	2.10	2.10	5.94	2.91	.....
31	2.30	.....	2.55	.....	2.00	2.10	.....	2.82	.....

a Observations discontinued from Jan. 1 to Mar. 9 and from Nov. 27 to Dec. 31 on account of ice.

Rating table for Elkhorn River near Norfolk, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.8	140	2.4	493	4.0	1,324	5.6	2,480
1.0	162	2.6	575	4.2	1,444	5.8	2,660
1.2	192	2.8	668	4.4	1,570	6.0	2,840
1.4	227	3.0	763	4.6	1,704	6.2	3,020
1.6	270	3.2	860	4.8	1,843	6.4	3,200
1.8	319	3.4	971	5.0	1,987	6.6	3,380
2.0	370	3.6	1,087	5.2	2,135	6.8	3,560
2.2	425	3.8	1,205	5.4	2,300		

[a] This table was applied indirectly according to the method outlined on page 323 of Nineteenth Ann. Rept. U. S. Geol. Surv., pt. 4.

Estimated monthly discharge of the Elkhorn River near Norfolk, Nebr.

[Drainage area, 2,474 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
March, 18 days	.....	.....	591	21,100	0.24	0.16
April	1,028	444	651	38,730	.26	.29
May	773	471	616	37,870	.25	.29
June	840	259	490	29,154	.20	.22
July	1,462	287	710	43,650	.29	.33
August	729	263	354	21,764	.14	.16
September	2,750	319	642	38,200	.26	.29
October	2,597	668	1,265	77,770	.51	.59
November 1 to 23	.....	.....	482	21,990	.19	.16

LOUP RIVER AT COLUMBUS, NEBR.

Observations at this station were begun October 13, 1894.

This station is located near the iron bridge of the Union Pacific Railway, just west of Columbus, Nebr. The observer is David J. Mowery, who lives in Columbus. The gage is 50 yards from the bridge, and is of oak, 3 by 6 inches, 12 feet long, fastened by lag screws to a pile, which forms part of the training works above the bridge. The rod is vertical. The 12-foot mark on the rod is 7 feet below a point 2 feet east of the third panel point of the north truss of the east span, counting the end of the span as the first panel point. Bench mark 2 is the regulation 4-foot iron post of the United States Geological Survey, placed 72 feet east of gage rod. Its elevation is 13.27 feet above zero of gage. Gagings are made from a cable which spans the stream about 50 yards above the bridge.

Discharge measurements of Loup River at Columbus, Nebr.

Date.	Hydrographer.	Gage height.	Dischar
1902.		*Feet.*	*Second-f*
March 8	Frank Dobson	5.79	6,
April 13	do	4.76	2,
May 11	do	4.81	2,
May 22	J. C. Stevens	5.56	4,
June 1	do	4.85	2,
July 11	do	5.59	6,
August 10	do	6.10	7,
August 26	do	5.55	6,
September 11	do	4.48	2,
October 5	J. C. Stevens and Ferd Bonstedt	5.05	3,

Daily gage height, in feet, of Loup River at Columbus, Nebr.[a]

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	N
1902.									
1		4.65	4.80	4.85	6.00	4.80	5.40	5.00	
2		4.60	4.80	4.95	6.60	4.70	5.10	5.00	
3		4.55	4.80	5.00	6.80	4.60	4.60	5.00	
4		4.50	4.85	5.40	6.10	4.60	4.55	5.00	
5		4.60	4.90	5.80	6.10	4.55	4.50	4.92	
6		4.80	5.00	5.90	6.05	4.50	4.50	4.95	
7		4.70	5.10	5.95	6.10	4.45	4.50	4.95	
8	5.79	4.70	5.00	5.00	6.00	4.40	4.45	4.90	
9	5.79	4.70	4.95	4.90	5.90	5.00	4.45	4.80	
10	5.00	4.70	4.90	4.85	6.45	6.10	4.45	4.80	
11	4.70	4.70	4.80	4.70	5.59	4.90	4.48	5.00	
12	4.60	4.73	4.80	4.65	5.25	4.70	4.45	5.60	
13	4.70	4.76	4.90	4.65	5.00	4.65	4.40	5.50	
14	4.80	4.75	5.10	4.60	5.50	4.62	4.40	5.40	
15	4.80	4.75	5.30	4.60	5.25	4.60	4.35	5.30	
16	4.80	4.70	5.30	4.70	5.10	4.60	4.30	5.20	
17	4.70	4.70	5.30	4.65	5.05	4.60	4.20	5.10	
18	4.70	4.70	5.70	4.65	5.10	5.00	4.40	5.00	
19	4.60	4.70	5.90	5.00	5.10	5.55	4.50	4.90	
20	4.60	4.70	6.10	5.40	5.00	5.50	4.65	4.90	
21	4.64	4.70	5.56	5.00	4.90	5.50	4.80	4.90	
22	4.65	4.75	5.55	4.95	4.80	5.40	5.80	4.90	
23	4.68	4.80	5.50	4.70	4.75	5.40	6.10	4.90	
24	4.70	4.80	5.40	4.80	4.70	5.30	5.10	4.90	
25	4.80	4.80	5.36	4.70	4.80	5.50	5.10	4.90	
26	4.90	4.85	5.15	4.60	4.85	5.55	5.10	4.90	
27	4.95	5.15	5.00	4.80	4.80	5.45	5.40	4.90	
28	4.97	5.10	4.95	4.80	4.85	5.50	5.20	4.85	
29	5.00	5.00	4.90	5.00	4.85	5.59	5.10	4.85	
30	4.80	4.90	4.85	5.00	4.85	5.80	5.05	4.80	...
31	4.70	.....	4.85	.....	4.80	5.95	.....	4.80	...

[a] Observations discontinued from January 1 to March 8, and from November 29 to Decei 31, on account of ice.

Rating table for Loup River at Columbus, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.8	1,140	4.6	2,040	5.4	4,101	6.2	6,760
3.9	1,175	4.7	2,265	5.5	4,402	6.3	7,134
4.0	1,225	4.8	2,500	5.6	4,712	6.4	7,517
4.1	1,300	4.9	2,743	5.7	5,031	6.6	8,311
4.2	1,400	5.0	2,995	5.8	5,358	6.8	9,149
4.3	1,510	5.1	3,258	5.9	5,694	7.0	10,025
4.4	1,660	5.2	3,530	6.0	6,040	7.2	10,941
4.5	1,825	5.3	3,811	6.1	6,396		

[a] This table was applied indirectly according to the method outlined on page 323, 19th Ann. Rept., U. S. Geol. Surv., pt. iv.

Estimated monthly discharge of the Loup River at Columbus, Nebr.

[Drainage area, 13,542 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
March, 24 days			3,343	159,156	0.25	0.22
April	3,206	1,976	2,409	143,385	.18	.20
May	7,443	2,203	3,226	198,334	.24	.28
June	5,936	2,211	3,250	193,375	.24	.27
July	10,895	3,394	5,669	348,530	.42	.48
August	8,152	2,463	4,767	293,115	.35	.40
September	6,909	1,693	3,218	191,487	.24	.27
October	4,712	2,500	3,011	185,116	.22	.25
November, 29 days	2,869	2,040	2,501	143,859	.19	.20

PLATTE RIVER NEAR COLUMBUS, NEBR.

This station was established in 1895, and is located on the left bank of the main channel of the river, 75 feet above the Meridian bridge south of Columbus. It is about 4 miles above the mouth of the Loup River. The gage consists of an inclined oak timber fastened to cross-ties which are embedded in the bank of the river. The channel is straight both above and below the gage. The bench mark is a standard 4-foot iron post of the United States Geological Survey, and is located 44.5 feet east of the gage, 60 feet north of the north end of the north bridge truss, and 10 feet west of a cottonwood tree 6 inches in diameter. Its elevation is 7.06 feet above gage datum.

The initial point for soundings is the north end of the upstream side of the bridge.

David J. Mowery, who lives in Columbus, is the observer.

Discharge measurements of Platte River near Columbus, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 8	Frank Dobson	3.39	5,664
April 13	do	2.22	996
May 11	do	2.37	1,695
May 22	J. C. Stevens	3.85	8,447
June 1	do	3.39	5,852
July 11	do	3.55	6,992
August 10	do	1.31	350
August 26	do	1.60	546
September 11	do	.50	5
October 5	J. C. Stevens and Ferd Bonstedt	2.50	1,989

Daily gage height, in feet, of Platte River near Columbus, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
1	.....	2.80	2.30	3.38	3.40	1.90	1.10	1.95	1.80
2	.....	2.60	2.25	3.39	3.60	1.80	1.10	2.00	1.90
3	.....	2.40	2.20	3.39	3.60	1.70	1.10	2.20	1.95
4	.....	2.30	2.40	3.40	4.00	1.50	1.00	2.40	2.00
5	.....	2.35	2.50	3.55	4.10	1.35	1.00	2.50	2.00
6	.....	2.10	2.65	3.90	4.10	1.20	1.00	2.75	2.00
7	(a)	2.15	2.75	3.80	4.00	1.10	1.10	2.75	2.00
8	3.39	2.15	2.85	3.85	4.00	1.05	1.00	2.50	1.95
9	3.38	2.20	2.85	3.70	3.90	1.00	.90	2.30	1.90
10	3.30	2.20	2.86	3.65	3.75	1.30	.80	2.30	1.90
11	3.00	2.20	2.87	3.50	3.50	1.10	.50	2.40	1.80
12	2.90	2.21	2.90	3.40	3.40	1.00	.45	2.80	1.70
13	2.80	2.22	2.90	3.20	3.20	.90	.40	3.00	1.70
14	2.80	2.20	3.00	3.20	3.21	1.10	.40	3.20	1.8[illegible]
15	2.80	2.20	3.20	3.05	3.00	1.20	.30	3.30	2.0[illegible]
16	2.80	2.15	3.35	3.25	2.89	1.10	.20	3.00	2.0[illegible]
17	2.70	2.15	3.45	3.40	2.80	1.00	.20	2.95	2.10
18	2.40	2.10	4.00	3.55	2.80	1.00	.20	2.90	2.10
19	2.30	2.10	4.30	3.55	3.05	1.00	.40	2.60	2.05
20	2.20	2.15	4.20	3.50	3.38	1.00	.65	2.50	2.05
21	2.20	2.10	3.85	3.50	3.00	1.40	.70	2.40	2.10
22	2.10	2.05	3.84	3.50	2.90	2.20	1.00	2.30	2.10
23	2.10	1.95	3.82	3.40	2.80	2.00	1.85	2.20	2.10
24	2.50	1.97	3.80	3.40	2.70	1.90	1.85	2.10	2.10
25	2.70	2.00	3.75	3.40	2.60	1.60	1.85	2.05	2.05
26	3.00	2.10	3.70	3.40	2.50	1.20	1.90	2.05	2.05
27	3.10	2.00	3.60	3.40	2.40	1.30	1.95	2.00	2.00
28	3.10	2.10	3.50	3.42	2.30	1.30	1.95	1.95	1.95
29	3.10	2.15	3.30	3.40	2.20	1.30	1.90	1.85	1.95
30	3.00	2.25	3.38	3.40	2.10	1.30	1.85	1.85	(a)
31	2.90	.....	3.38	.....	2.05	1.20	.....	1.85	.....

a Observations discontinued from January 1 to March 8 and from November 29 to December 31 on account of ice.

Rating table for Platte River near Columbus, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	190	2.0	825	3.0	3,100	4.0	9,150
1.1	220	2.1	925	3.1	3,500	4.2	11,250
1.2	250	2.2	1,025	3.2	4,000	4.4	13,550
1.3	285	3.3	1,150	3.3	4,500	4.6	16,400
1.4	340	2.4	1,275	3.4	5,000	4.8	19,700
1.5	400	2.5	1,400	3.5	5,500	5.0	23,700
1.6	475	2.6	1,676	3.6	6,050	5.2	28,400
1.7	550	2.7	1,984	3.7	6,700	5.4	33,700
1.8	635	2.8	2,324	3.8	7,400	.....	.....
1.9	725	2.9	2,696	3.9	8,200	.....	.....

[a] This table was applied indirectly according to the method outlined on page 323, 19th Ann. Rept. U. S. Geol. Surv., Pt. IV.

Estimated monthly discharge of the Platte River near Columbus, Nebr.

[Drainage area 56,867 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
March 9 to 31	.....	.....	2,817	134,098	0.050	0.045
April	2,398	825	1,076	64,022	.019	.021
May	13,800	1,212	5,462	335,845	.096	.111
June	9,950	4,150	6,426	382,347	.113	.126
July	11,140	995	5,267	323,805	.093	.107
August	1,150	190	404	24,837	.007	.008
September	975	0	337	20,051	.006	.007
October	5,000	690	1,798	110,554	.032	.037
November	925	635	796	47,365	.014	.016

PLATTE RIVER NEAR LEXINGTON, NEBR.

This station was established April 2, 1902, by H. O. Smith. It is located on the highway bridge, 2½ miles south of Lexington, Nebr. The gage is of the usual wire type, the scaleboard being graduated to feet and half-tenths. It is protected by a box and securely fastened to the upstream hand rail of the bridge, about 100 feet from the north end. It is read daily by Charles Freeman, a farmer living near by. The channel is straight both above and below the station.

The banks are low, but do not overflow. The bed of the stream is sandy and shifting. Bench mark No. 1 is a hub on the west side of the bridge approach. Its elevation is 2,391.90 feet above sea level. Bench mark No. 2 is the top of the east end of the first cap at the north end of bridge. Its elevation is 2,393.31 feet above sea level. The elevation of the water surface, or the end of the weight, when the gage reads zero, is 2,385.65 feet.

Discharge measurements of Platte River near Lexington, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 8	H. O. Smith and B. E. Forbes	[illegible]	[illegible]
May 2	H. O. Smith	2.85	[illegible]
May 22	do	3.38	7,70[illegible]
June 3	do	3.00	3,03[illegible]
June 18	do	3.25	6,55[illegible]
July 5	do	2.98	4,[illegible]
July 19	do	2.30	1,0[illegible]
July 29	do	2.25	1[illegible]
August 2	do	2.00	[illegible]
August 23	do	1.20	[illegible]
September 25	do	2.85	2,[illegible]
November 8	do	2.70	1,[illegible]

Daily gage height, in feet, of Platte River near Lexington, Nebr.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	.....	2.95	3.25	.....	2.35	1.70	2.45	2.70
2	.....	2.85	2.95	.....	2.00	1.60	2.55	2.60
3	.....	2.80	2.90	.....	1.95	1.50	2.55	2.65
4	.....	2.75	3.00	.....	1.80	1.45	2.50	2.45
5	.....	2.85	2.90	3.00	1.80	1.40	2.50	2.60
6	.....	2.80	2.90	3.00	1.70	1.40	2.40	2.60
7	.....	2.90	2.55	2.90	1.65	1.35	2.45	2.75
8	.....	2.90	2.75	3.05	1.60	1.30	2.55	2.70
9	.....	2.70	3.15	2.70	1.85	1.20	2.50	(a)
10	.....	2.75	.....	3.00	1.65	1.15	2.45	.....
11	.....	2.75	3.00	2.90	1.60	1.10	2.70	.....
12	.....	2.75	3.05	3.00	1.50	1.10	2.75	.....
13	.....	2.90	3.40	3.05	1.45	1.10	2.75	.....
14	.....	3.10	3.35	2.65	1.40	1.05	2.70	.....
15	2.70	3.40	3.15	2.80	1.40	1.00	2.65	.....
16	2.65	3.40	3.30	2.50	1.35	1.00	2.65	.....
17	2.65	3.95	3.00	2.50	1.30	1.00	2.60	.....
18	2.60	3.70	3.25	2.35	1.30	0.95	2.65	.....
19	2.70	3.60	3.25	2.30	1.25	0.95	2.65	.....
20	2.75	3.40	3.25	2.25	1.20	0.90	2.80	.....

[a] Book stolen containing records from November 9.

ily gage height, in feet, of Platte River near Lexington, Nebr.—Continued.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
	2.70	3.20	3.10	2.25	1.20	1.60	2.70	.....	2.65
	2.60	3.35	3.35	2.15	1.20	2.10	2.60	.....	2.60
	2.60	3.40	3.20	2.10	1.25	2.05	2.60	.....	2.70
	2.75	3.30	3.40	2.05	1.30	2.25	2.60	.....	2.70
	2.65	3.20	3.40	2.00	1.40	2.85	2.60	.....	2.80
	2.60	3.20	3.10	2.40	1.45	2.35	2.60	.....	2.70
	2.90	3.25	3.10	2.40	1.35	2.70	2.65	.....	2.80
	2.70	3.30	(a)	2.35	1.30	2.70	2.80	.....	2.85
	2.75	3.40	.....	2.15	1.25	2.40	2.65	.....	2.85
	2.80	3.35	.....	2.40	2.15	2.45	2.70	.....	3.00
	.....	3.30	.....	2.30	2.00	.....	2.70	.....	3.00

[a] Gage down; bridge being repaired.

Rating table for Platte River near Lexington, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.1	160	2.6	1,680	3.1	5,140	3.6	10,240
2.2	390	2.7	2,220	3.2	6,060	3.7	11,520
2.3	640	2.8	2,820	3.3	7,000	3.8	12,860
2.4	920	2.9	3,500	3.4	8,020	3.9	14,240
2.5	1,260	3.0	4,290	3.5	9,060	4.0	15,680

[a] This table was applied indirectly, according to the method outlined on p. 323, 19th An. Rept., U. S. Geol. Surv., Pt. IV.

Estimated monthly discharge of the Platte River near Lexington, Nebr.

[Drainage area, 53,300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
ril 15 to 30	.....	.....	2,208	70,072	0.041	0.024
ly	14,672	1,950	5,490	337,550	.103	.119
ne, 26 days	.....	.....	5,135	264,813	.096	.092
y	5,692	0	2,234	137,350	.042	.048
gust	565	0	27	1,660	.001	.001
tember	2,780	0	302	17,968	.006	.007
ober	1,896	640	1,191	73,232	.022	.025
ember	4,290	275	1,678	103,160	.031	.036

NORTH PLATTE RIVER AT NORTH PLATTE, NEBR.

The lowest gaging station on this river is located at the wagon bridge just north of North Platte, Nebr., and was established October 5, 1894. It is 3.5 miles above the junction with the South Platte River. The bridge is a long, low, pile bridge, having 93 spans of approximately 20 feet each, crossing the main channel of the river. North of this, at a distance of about 440 feet, is another bridge crossing a smaller branch or slough, and having six spans of about 20 feet each. The water, except in times of flood, does not pass under all of the spans of the long bridge. Usually the greater part flows under two or three of the spans, spreading out in shallow pools or streamlets under others. Beneath the greater number of spans is a dry, sandy bed at ordinary stages. The initial point for soundings is on the right bank and consists of a mark on the railing on the upstream side of the bridge. The channel is nearly straight for about 500 feet both above and below the station. The banks are low, but are rarely, if ever, overflowed.

The observations of river height are made at the Union Pacific Railroad bridge, about 2 miles below the wagon-road bridge. The railroad bridge is 3 miles above the junction of the North and South Platte rivers. The gage is vertical, marked to tenths of a foot, and is fastened by screws to the piling under the bridge. The top of the east rail directly over the gage is 12 feet above the zero. The gage rod is read twice each day by H. E. Dress, the railroad bridge watchman.

Discharge measurements of North Platte River at North Platte, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 9	H. O. Smith and B. E. Forbes	2.20	1,804
May 6	H. O. Smith	2.65	3,723
May 20	do	3.15	7,136
June 3	do	2.50	3,039
June 19	do	3.00	6,610
July 3	do	2.70	4,991
July 17	do	1.65	1,343
July 28	do	1.70	678
August 9	do	1.00	55
August 18	do	1.00	49
August 23	do	1.00	94
September 6	do	1.00	20
September 24	do	2.30	1,817
November 29	do	2.40	822

Rating table for North Platte River at North Platte, Nebr.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.5	15	1.5	565	2.5	2,950	3.5	11,100
.6	30	1.6	670	2.6	3,440	3.6	12,700
.7	50	1.7	800	2.7	4,050	3.7	14,300
.8	75	1.8	950	2.8	4,700	3.8	16,000
.9	100	1.9	1,120	2.9	5,450	3.9	17,700
1.0	150	2.0	1,320	3.0	6,100	4.0	19,400
1.1	210	2.1	1,560	3.1	6,900		
1.2	280	2.2	1,800	3.2	7,800		
1.3	370	2.3	2,150	3.3	8,800		
1.4	465	2.4	2,520	3.4	9,900		

[a] This table was applied indirectly according to the method outlined on p. 323, 19th An. Rept. U. S. Geol. Surv., Part IV.

Daily gage height, in feet, of North Platte River at North Platte, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.										
1	.....	2.00	2.70	2.60	2.80	1.50	1.10	1.90	2.00	2.20
2	.....	2.25	2.70	2.60	2.80	1.35	1.05	1.90	2.00	2.25
3	.....	2.30	2.60	2.50	2.70	1.20	1.00	1.90	2.00	2.30
4	.....	2.40	2.60	2.50	2.60	1.10	1.00	1.95	2.00	2.30
5	.....	2.40	2.70	2.45	2.50	1.10	1.00	2.00	2.00	2.30
6	.....	2.40	2.65	2.65	2.50	1.15	1.00	1.95	2.00	2.30
7	.....	2.25	2.60	2.95	2.50	1.00	1.00	1.90	2.00	(a)
8	.....	2.20	2.60	2.90	2.40	1.00	1.00	1.85	2.00	.....
9	.....	2.20	2.60	3.00	2.50	1.00	1.00	1.75	2.00	.....
10	.....	2.15	2.60	2.90	2.35	1.05	.95	1.70	2.00	.....
11	.....	2.10	2.60	2.75	2.30	1.00	1.00	2.05	2.00	.....
12	.....	2.00	2.75	3.05	2.20	.90	1.10	2.00	2.00	.....
13	.....	2.05	2.90	2.95	2.10	.90	1.15	2.00	2.00	.....
14	.....	2.15	2.90	3.00	2.00	1.05	1.10	2.00	2.00	.....
15	(a)	2.30	3.00	3.00	2.00	1.05	1.20	2.00	2.10	.....
16	1.80	2.40	3.40	3.00	1.75	1.00	1.15	2.00	2.10	.....
17	2.05	2.40	3.20	2.95	1.50	.90	1.10	2.00	2.10	.....
18	2.20	2.35	3.05	3.00	1.60	1.00	1.20	1.95	2.10	.....
19	2.20	2.40	3.10	3.00	1.70	1.10	1.15	1.90	2.10	.....
20	2.25	2.40	3.15	3.00	1.70	1.10	1.10	1.90	2.10	.....
21	2.30	2.40	3.15	2.90	1.70	1.00	1.20	2.00	2.05	.....
22	2.30	2.55	3.10	2.90	1.60	1.00	1.55	2.00	2.00	.....
23	2.35	2.60	3.10	2.90	1.60	1.00	2.25	2.00	2.05	.....
24	2.55	2.60	3.10	2.80	1.50	1.05	2.30	2.00	2.10	.....
25	2.60	2.60	3.10	2.65	1.40	1.10	2.15	2.00	2.10	.....
26	2.65	2.50	3.05	2.60	1.40	1.00	1.95	2.00	2.20	.....
27	2.50	2.60	3.00	2.60	1.45	1.00	1.95	2.00	2.60	.....
28	2.45	2.60	2.90	2.50	1.65	1.10	2.00	2.00	2.50	.....
29	2.30	2.60	2.90	2.50	1.80	1.20	2.00	1.90	2.40	.....
30	2.05	2.60	2.90	2.70	1.65	1.10	1.90	1.90	2.20	.....
31	2.00	.....	2.80	.....	1.50	1.10	.....	2.00	.....	.....

[a] River frozen.

Estimated monthly discharge of the North Platte River at North Platte, N

[Drainage area 28,517 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	De in
1901.						
March	9,900	1,320	3,260	200,425	0.110	
April	4,700	1,560	2,408	143,276	.080	
May	14,300	2,150	7,680	472,232	.270	
June	17,700	4,050	9,733	579,108	.340	
July	4,050	75	1,508	92,712	.050	
August	800	50	346	21,275	.010	
September	1,320	565	1,068	63,546	.040	
October	1,320	670	1,121	68,919	.040	
November	1,800	1,320	1,576	93,772	.060	
1902.						
March 16 to 31			2,257	71,627	.079	
April	3,440	1,800	2,443	145,359	.086	
May	9,900	3,440	5,450	335,066	.191	
June	6,900	2,950	5,139	305,790	.180	
July	6,100	370	2,229	137,039	.078	
August	370	30	102	6,271	.004	
September	1,800	100	481	28,620	.017	
October	1,120	670	1,035	63,642	.036	
November	1,560	800	1,104	65,688	.039	

NORTH PLATTE RIVER AT BRIDGEPORT, NEBR.

This station was established May 4, 1902, by R. H. Willis. located at the wagon bridge, one-half mile due north from Bridge Nebr. The gage is of the usual wire type, the scaleboard being uated to half-tenths of feet. It is inclosed in a wooden box sec fastened to the railing of the bridge. When the gage reads zer water is 9 feet below the floor of the bridge at the gage. The ga read daily by Frank Churchill, a schoolboy who lives one-half away. The discharge measurements are made from the bridge the initial point for sounding is on the right bank at the south e the west railing of the bridge. The channel widens both above below the station. The banks are low, but not liable to over The bed of the stream is sandy and shifting. The bench mark i top of the floor of the bridge at the gage. Its elevation is 9 above the surface of the water when the gage reads zero.

The following discharge measurements were made by R. H. Willis and Frank Dobson in 1902:

May 20: Gage height, 6.00 feet; discharge, 5,414 second-feet.
June 3: Gage height, 5.80 feet; discharge, 4,515 second-feet.
June 10: Gage height, 5.17 feet; discharge, 2,050 second-feet.
June 14: Gage height, 5.97 feet; discharge, 5,433 second-feet.
June 21: Gage height, 5.71 feet; discharge, 5,120 second-feet.
July 19: Gage height, 5.00 feet; discharge, 787 second-feet.
July 26: Gage height, 4.87 feet; discharge, 619 second-feet.
August 8: Gage height, 4.68 feet; discharge, 190 second-feet.
August 28: Gage height, 4.49 feet; discharge, 37 second-feet.
September 22: Gage height, 5.08 feet; discharge, 634 second-feet.

Daily gage height, in feet, of North Platte River at Bridgeport, Nebr.

Day.	May.	June.	July	Aug.	Sept.	Oct.	Nov.
1902.							
1	.....	5.41	5.60	4.85	4.50	4.79	5.02
2	.....	5.61	5.56	4.75	4.46	4.75	4.95
3	.....	5.79	5.76	4.80	4.45	4.80	4.98
4	5.50	5.93	5.40	4.78	4.44	4.80	4.88
5	5.70	6.04	5.43	4.80	4.40	4.84	4.96
6	5.60	5.99	5.32	4.79	4.40	4.82	5.00
7	5.56	6.10	5.33	4.80	4.40	4.80	(a)
8	5.60	5.93	5.35	.....	4.40	4.82	.....
9	5.68	5.89	5.27	4.75	4.48	4.85	.....
10	.....	5.90	5.16	4.72	4.40	4.85	.....
11	.....	5.93	5.19	4.72	4.40	4.91	.....
12	5.76	5.92	5.10	4.70	4.40	4.95	.....
13	.....	5.89	5.02	4.67	4.40	4.90	.....
14	5.80	6.00	5.04	5.05	4.38	4.91	.....
15	5.89	6.04	5.00	4.75	4.41	4.94	.....
16	5.86	6.00	5.20	4.68	4.40	4.95	.....
17	5.91	6.00	5.04	4.70	4.40	4.92	.....
18	5.99	5.85	5.01	4.65	4.40	4.95	.....
19	5.95	5.82	5.00	4.62	.....	4.91	.....
20	6.00	5.82	4.89	4.61	4.46	4.92	.....
21	6.04	5.75	4.86	4.60	.....	.....	.....
22	6.10	5.68	4.80	4.59	4.95	4.94	.....
23	6.04	5.58	4.75	4.60	4.88	4.95	.....
24	6.04	5.48	4.77	4.62	4.78	4.95	.....
25	5.96	5.47	4.86	4.52	4.77	4.94	.....
26	5.86	5.26	4.90	4.52	4.95	4.95	.....
27	5.65	5.46	4.94	4.56	4.85	4.90	.....
28	5.56	5.60	4.79	4.60	4.82	4.91	5.00
29	5.41	5.87	4.76	.....	4.82	4.95	.....
30	5.45	5.85	4.85	.....	4.79	4.94	.....
31	5.41	.....	4.90	.....	.....	4.91	.....

[a] Observations discontinued November 6 to December 31 on account of ice.

Rating table for North Platte River at Bridgeport, Nebr., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.4	10	4.9	560	5.4	2,120	5.9	4,820
4.5	50	5.0	790	5.5	2,610	6.0	5,450
4.6	110	5.1	1,060	5.6	3,120	6.1	6,200
4.7	210	5.2	1,380	5.7	3,660		
4.8	350	5.3	1,710	5.8	4,230		

Estimated monthly discharge of the North Platte River at Bridgeport, Nebr.

[Drainage area, 23,190 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
May, 25 days			4,149	255,050	0.179	0.206
June	6,200	1,580	4,267	253,900	.184	.205
July	4,000	290	1,200	73,780	.052	.060
August, 27 days			244	15,000	.011	.013
September, 28 days			162	9,640	.007	.008
October, 30 days			559	34,372	.024	.028

NORTH PLATTE RIVER AT MITCHELL, NEBR.

This station was established by O. V. P. Stout on June 3, 1901. It replaces the station at Gering, Nebr., which was discontinued, as the narrower channel at Mitchell seemed favorable to increased accuracy of gagings, and, being nearer the Wyoming line, it serves better as a State-line gaging station.

The gage consists of a sash weight hung from a wire carrying an index reading on a horizontal rod nailed to the bridge rail. The zero of the gage is 8 feet below the bridge floor at the gage. It is also 6.73, 6.79, and 6.79 feet below the tops of the upstream ends of the bridge. The observer is G. D. Aughinbaugh, a barber at Mitchell, about one-half mile from the bridge.

On April 4, 1902, a temporary gage rod was set whose zero mark was 3.79 lower than the old rod of 1901. On May 3, 1902, a new permanent gage was put in whose zero mark was 1.0 foot lower than the old rod of 1901, in order to avoid negative gage heights. Hence, between April 4 and May 3, 1902, 2.79 feet were subtracted from the gage heights reported by the observer. To make the gage heights reported during 1901 comparable with those of 1902, 1.0 foot must be added.

Discharge measurements of North Platte River at Mitchell, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet*	*Sec.-feet.*
April 4	Frank Dobson	1.56	917
May 3	do	2.22	2,649
May 28	do	2.46	3,698
June 12	do	3.15	6,425
June 19	do	3.00	4,937
June 27	do	2.42	3,257
July 16	do	1.58	1,014
July 24	do	1.30	630
August 2	do	1.05	349
August 19	do	.85	102
September 2	do	.82	30
October 25	R. H. Willis	.96	363

Daily gage height, in feet, of North Platte River at Mitchell, Nebr.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	.....	2.26	2.79	2.30	1.21	0.82	0.86	0.95
2	.....	2.36	2.91	2.65	1.23	.82	.86	.94
3	(a)	2.22	3.05	2.22	1.19	.83	.87	.94
4	1.56	2.42	3.17	2.05	1.13	.83	.87	.93
5	1.56	2.27	3.25	1.89	1.14	.82	.87	.94
6	1.56	2.32	3.27	1.91	1.14	.82	.87	1.08
7	1.31	2.43	3.05	1.90	1.00	.82	.93	1.09
8	1.21	2.47	3.05	1.91	1.03	.83	.....	1.08
9	1.31	2.48	3.02	1.90	1.04	.83	.....	1.08
10	1.27	2.65	3.17	1.85	1.00	.82	.....	1.11
11	1.27	2.75	3.11	1.76	.98	.82	.....	1.09
12	1.41	2.70	3.16	1.69	.95	.82	.89	1.10
13	1.51	2.80	3.14	1.69	.90	.82	.93	1.10
14	1.61	2.95	3.14	1.76	.93	.83	.93	1.10
15	1.71	3.01	3.19	1.61	.90	.83	.91	1.10
16	1.91	3.07	3.10	1.60	.87	.83	.93	1.14
17	1.81	3.14	3.05	1.54	.86	.83	.92	1.10
18	1.81	3.14	3.01	1.46	.85	.83	.91	1.75
19	1.86	3.19	3.03	1.41	.85	.82	.93	1.15
20	1.86	3.19	2.99	1.38	.85	.84	.93	1.18
21	1.91	3.02	2.94	1.37	.84	.85	.94	1.17
22	1.86	3.27	2.76	1.37	.84	.88	.96	1.16
23	1.86	3.19	2.64	1.39	.84	.89	.97	.....
24	2.26	3.15	2.51	1.38	.84	.85	.97	.....
25	2.21	3.05	2.32	1.28	.84	.84	.98	.....
26	2.41	2.90	2.21	1.31	.84	.85	.99	.....
27	2.41	2.70	2.30	1.29	.84	.84	.98	.....
28	2.51	2.52	2.20	1.25	.84	.87	.99	.....
29	2.46	2.49	2.53	1.46	.83	.86	1.00	.....
30	2.36	2.39	2.39	1.50	.83	.86	.99	.....
31	.....	2.20	.....	1.31	.83	.....	.97	.....

[a] Observations discontinued from January 1 to April 4 and from November 22 to December 31 on account of ice.

Rating table for North Platte River at Mitchell, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.0	99	1.2	1,650	2.4	4,595	3.6	9,920
.2	235	1.4	2,020	2.6	5,290	3.8	11,022
.4	455	1.6	2,455	2.8	6,100	4.0	12,120
.6	720	1.8	2,910	3.0	7,015	.....	.....
.8	1,005	2.0	3,415	3.2	7,940	.....	.....
1.0	1,310	2.2	3,980	3.4	8,900	.....	.....

[a] This table was applied indirectly, according to the method outlined, p. 323, 19th An. U. S. Geol. Surv., Pt. IV.

Estimated monthly discharge of the North Platte River at Mitchell, Nebr.

[Drainage area, 24,400 square miles.]

Month.	Discharge (second-feet).			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April 4 to 30	.....	.....	1,603	85,846	0.066	0.067
May	6,373	2,649	4,346	267,200	.178	.205
June	6,877	2,934	4,915	292,420	.201	.224
July	3,777	612	1,308	80,420	.054	.062
August	559	44	207	12,728	.008	.009
September	124	30	69	4,105	.003	.003
October, 24 days	.....	.....	299	14,233	.012	.011
November 1 to 22	.....	.....	563	24,567	.023	.019

NORTH PLATTE RIVER AT GUERNSEY, WYO.

This station was established June 14, 1900, by A. J. Parshall. It is located at the county bridge about a half mile northwest of Guernsey. The bridge has eight piers, the sides are planked, and there is uniform flow under each span. The rod consists of a 4-inch by 4-inch by 12-foot scantling firmly attached to one of the piers of the bridge. As the station was to be a temporary one, a metallic tape, divided into feet and tenths, was securely fastened to the rod. The bench mark is a spike driven into a sleeper of the bridge 1 foot from the rod and at an elevation of 10.04 feet above the zero. The channel is straight for a distance above and below the station. Both banks are high and do not overflow at high stages. The bed of the stream is sandy, but probably does not shift much.

It was found that considerable inconvenience was caused by sand accumulating about the rod as the high water subsided. With the opening of the season of 1902 a new rod was placed about 200 feet

the first location. It was fastened to one of the piers of the l bridge, and was placed 1 foot lower in the water.
urements are still made from the county bridge, which, while not furnish a perfect location for measurements, is the best nd on the river in Wyoming.

Discharge measurements of North Platte River at Guernsey, Wyo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
8	A. J. Parshall	0.90	1,099
	do	.65	748
	do	1.50	1,696
	do	2.10	3,025
	do	3.80	7,379
ber 5	do	− .30	173
9	do	.20	437

Daily gage height, in feet, of North Platte River at Guernsey, Wyo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
	0.90	2.20	3.80	1.60	0.50	−0.20	0.20	0.30	0.40
	.90	2.40	3.80	1.60	.50	− .20	.20	.30	.40
	.65	2.40	3.80	1.60	.50	− .30	.20	.30	.40
	.65	2.40	4.00	1.60	.50	− .30	.20	.30	.40
	.65	2.60	4.00	1.80	.40	− .30	.20	.30	.40
	.80	2.60	4.00	1.60	.40	− .25	.20	.30	.40
	.80	2.80	4.00	1.20	.40	− .30	.20	.30	.40
	.90	2.80	4.00	1.60	.40	− .30	.20	.30	.40
	1.00	2.80	4.00	1.20	.20	− .30	.20	.30	.40
	1.00	3.00	3.80	1.20	.40	− .30	.20	.30	.40
	1.00	3.00	3.80	1.20	.40	− .30	.20	.30	.40
	1.05	3.20	4.00	1.20	.20	− .20	.20	.30	.30
	1.25	3.20	4.00	1.00	.20	− .20	.20	.30	.30
	1.40	3.20	3.80	1.00	.20	− .30	.20	.30	.30
	1.60	3.20	3.80	1.00	.20	− .20	.20	.30	.30
	1.60	4.10	3.80	1.00	.00	− .20	.20	.30	.60
	1.60	3.80	3.40	.80	.00	− .30	.20	.30	.60
	1.50	4.00	3.40	.80	.00	− .30	.20	.30	.60
	1.60	3.80	3.40	.80	.00	− .30	.20	.40	.60
	1.60	3.80	3.00	1.00	.00	− .20	.20	.40	.60
	1.60	3.80	3.00	1.00	.00	− .20	.20	.40	.70
	1.90	3.80	3.00	1.00	.00	− .30	.20	.40	.70
	2.00	3.80	2.60	.80	.00	− .30	.20	.40	.70
	2.20	3.60	2.60	.80	− .10	− .30	.20	.40	.75
	2.20	3.00	2.60	.70	− .10	− .30	.20	.40	.70
	2.40	2.80	2.00	1.20	− .20	− .30	.20	.40	.70
	2.20	2.60	2.00	1.20	− .20	− .30	.20	.40	.70
	2.20	2.60	2.00	1.20	− .20	− .30	.20	.40	.80
	2.20	2.60	2.00	1.20	− .20	− .30	.30	.40	.80
	2.20	3.00	2.00	.80	− .20	.20	.30	.40	.80
		3.00		.80	− .20		.30		.80

Rating table for North Platte River at Guernsey, Wyo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.7	15	0.5	625	1.7	2,135	2.9	5,050
.6	50	.6	700	1.8	2,335	3.0	5,305
.5	90	.7	780	1.9	2,550	3.1	5,560
.4	130	.8	870	2.0	2,780	3.2	5,820
.3	175	.9	970	2.1	3,030	3.3	6,080
.2	220	1.0	1,080	2.2	3,280	3.4	6,340
.1	270	1.1	1,200	2.3	3,530	3.5	6,600
.0	320	1.2	1,330	2.4	3,780	3.6	6,860
.1	375	1.3	1,470	2.5	4,030	3.7	7,120
.2	430	1.4	1,620	2.6	4,285	3.8	7,380
.3	490	1.5	1,780	2.7	4,540	3.9	7,640
.4	555	1.6	1,950	2.8	4,795	4.0	7,900

Estimated monthly discharge of North Platte River at Guernsey, Wyo.

[Drainage area, 16,243 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	3,780	740	1,885	111,949	0.12	0.13
May	8,160	3,280	5,556	341,015	.34	.39
June	7,900	2,780	6,131	364,181	.38	.42
July	2,335	780	1,304	80,061	.08	.09
August	625	220	400	24,552	.02	.02
September	430	175	196	11,662	.01	.01
October	490	430	436	26,750	.03	.03
November	555	490	516	30,650	.03	.03
December	870	490	663	40,689	.04	.05

LITTLE LARAMIE RIVER NEAR HATTON, WYO.

This station was established in 1902 by B. P. Fleming. It is located at an old bridge 25 miles northwest of Laramie, Wyo. The gage is a plain staff graduated to feet and tenths and secured to the bridge. It is read twice daily by J. M. May, a ranchman, who lives about 75 yards from the gage. The initial point for soundings is a nail driven in the bridge stringer at the left bank. The channel is straight above the station and curved below. The water is quite swift. The right bank is liable to overflow. The left bank is high and rocky. There is an old channel at the right of the station in which there is flow at

ater. The bed of the stream is rocky and very rough. The mark is on a rock on the left bank of the stream near the gage. narked B. M. U. S. G. S. Its elevation above the zero of the as not been determined.

ng 1902 the following discharge measurements were made by Fleming:

ıly 5: Gage height, 1.05 feet; discharge, 159 second-feet.
ugust 21: Gage height, 0.47 foot; discharge, 30 second-feet.
ctober 14: Gage height, 0.68 foot; discharge, 51 second-feet.

Daily gage height, in feet, of Little Laramie River near Hatton, Wyo.

July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
.....	0.60	0.30	0.70	0.55	17.....	1.00	0.40	0.30	0.60	0.55
.....	.60	.30	.70	.55	18.....	1.15	.40	.30	.60	.60
.....	.60	.30	.70	.45	19.....	1.00	.35	.30	.60	.65
.....	.50	.30	.70	.45	20.....	.95	.30	.30	.60	.65
.....	.50	.30	.70	.45	21.....	.90	.35	1.20	.60	.70
1.00	.50	.30	.60	.45	22.....	.80	.30	1.25	.60	.65
1.00	.55	.20	.60	.45	23.....	.80	.30	1.00	.60	.65
.90	.55	.20	.60	.60	24.....	.80	.30	.80	.60	.60
.90	.55	.20	.60	.60	25.....	.80	.30	.80	.60	.65
.90	.40	.30	.60	.60	26.....	.80	.30	.80	.60	.60
.80	.45	.30	.70	.55	27.....	.80	.30	.80	.60	.55
.80	.55	.30	.70	.50	28.....	.75	.30	.70	.60	.55
.85	.50	.30	.70	.45	29.....	.65	.30	.75	.60	.60
.90	.50	.30	.70	.45	30.....	.60	.35	.70	.60	.60
.85	.55	.30	.70	.55	31.....	.65	.30	.....	.55	.....
.85	.45	.30	.60	.50						

Rating table for Little Laramie River near Hatton, Wyo., for 1902.

e ıt.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1	2.5	0.4	24.5	0.7	54.5	1.0	133
2	9.5	.5	32.5	.8	72.5	1.1	188
3	16.5	.6	41.5	.9	96	1.2	248

Estimated monthly discharge of Little Laramie River near Hatton, Wyo.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
31.....	.....	.....	91	4,695
.....	42	16	27	1,660
ber.....	278	10	48	2,856
'.....	54	42	46	2,828
ber.....	54	28	38	2,285

SWEETWATER RIVER AT DEVILS GATE, NEAR SPLITROCK, WYO.

This station was established in October, 1902, by W. W. Schlecht. It is located about one-fourth mile above Devils Gate and is reached by a team from Rawlins or from Casper, Wyo. The gage is of the usual wire type, with the scale board graduated to feet and tenths. It is read twice daily by Tom Sun, jr., a rancher who lives about 300 yards from the gage. The gagings are made temporarily from a foot bridge at Tom Sun's house. It is intended later to establish a cable at this point.

One discharge measurement made by W. W. Schlecht on October 4, 1902, gives gage height 4.02 feet; discharge, 14.5 second-feet.

Daily gage height, in feet, of Sweetwater River at Devils Gate, Wyo.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.											
1	4.05	.....	4.20	12	4.07	4.11	4.50	23	4.09	4.10	4.50
2	4.00	.....	4.40	13	4.06	4.11	4.50	24	4.09	4.05	4.55
3	4.02	.....	4.40	14	4.05	4.19	4.50	25	4.10	4.15	4.60
4	4.03	.....	4.40	15	4.04	4.14	4.40	26	.....	4.15	4.55
5	4.03	.....	4.40	16	4.03	4.00	4.40	27	.....	4.15	4.45
6	4.03	.....	4.50	17	4.06	4.05	4.40	28	.....	4.20	4.40
7	4.02	.....	4.40	18	4.07	4.00	4.40	29	.....	4.20	4.38
8	4.01	.....	4.45	19	4.05	4.05	4.45	30	.....	4.20	4.45
9	4.02	4.08	4.50	20	4.04	4.05	4.40	31	.....	.....	4.50
10	4.01	4.05	4.50	21	4.09	4.00	4.60				
11	4.03	4.10	4.50	22	4.09	4.10	4.50				

SOUTH PLATTE RIVER AT BIGSPRING, NEBR.

This station was established September 5, 1902, by J. C. Stevens. It is located on the highway bridge one-fourth mile south of Bigspring, Nebr. The gage is of the usual wire type, graduated to feet and tenths, and bolted to the girder of the bridge. It is read daily by Victor Root, a schoolboy, who lives near by. The measurements are made from the bridge, and the initial point for soundings is on the upstream side of the north end of the bridge. There is a short bend above the station and below the station the river is straight. The banks are not liable to overflow. The bed is sandy and shifting. The bench mark is a United States Geological Survey bench mark (marked "U. S. Geological Survey B. M. Elevation above sea, 3,370 feet"), located about 200 feet north of the Union Pacific depot, on the west side of the street. Its elevation is 3,370 feet above sea level. The elevation of the floor of the bridge over the zero mark of the gage is 3,373.95 feet. When the gage reads zero the surface of the water is 9.1 feet below the floor of the bridge over zero mark on the rod and 3,364.85 below bench mark described above.

Gage heights were taken of the water surface when there was no rface flow by digging in the sand.

Discharge measurements of South Platte River at Bigspring, Nebr.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
ptember 5	J. C. Stevens	1.00	0
ptember 23	H. O. Smith	1.65	173

Daily gage height, in feet, of South Platte River at Bigspring, Nebr.

Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.
1902.											
		1.80	1.45	12	1.00	1.35	1.35	23	1.65	1.35	1.30
2		1.80	1.45	13	1.00	1.35	1.30	24	1.50	1.25	1.30
3		1.80	1.45	14	1.00	1.35	1.30	25	2.00	1.25	1.30
4		1.80	1.45	15	1.00	1.30	1.30	26	2.40	1.20	1.35
5	1.00	1.60	1.40	16	1.00	1.35	1.30	27	2.15	1.25	1.35
6	1.05	1.60	1.30	17	1.10	1.35	1.30	28	1.90	1.25	1.30
7	1.00	1.60	1.25	18	1.10	1.25	1.30	29	1.80	1.25	1.45
8	1.00	1.50	1.25	19	1.15	1.25	1.30	30	1.80	1.25	(a)
9	1.00	1.50	1.25	20	1.20	1.25	1.35	31		1.35	
10	1.00	1.50	1.25	21	Pools.	1.20	1.30				
11	1.00	1.35	1.25	22	2.00	1.30	1.30				

a Observations were discontinued November 29.

SOUTH PLATTE RIVER AT JULESBURG, COLO.

This station was established April 2, 1902, by John E. Field, at the wagon bridge crossing the South Platte River, about 1 mile southeast of Julesburg, Colo., a station at the junction of the main line and Denver branch of the Union Pacific Railroad. As this is the last station on the South Platte River in Colorado, and is also below all irrigation ditches in Colorado taking water from the South Platte, with the exception of one, it is of considerable importance for securing data relative to the flow of return waters as well as the natural flow in the main channel. However, the conditions at this station are not as desirable as they should be, owing to the great width of the channel and the general instability of the bed of the stream, features characteristic of the whole course of the South Platte River through this part of the State. The channel at this point is about one-half mile wide, and at low stages of the river it is badly broken up by islands, causing the stream to flow in several different channels. The banks are low, but do not overflow. The bed of the river is dry during the greater part of the year and is shifting and unstable, being composed entirely of sand and gravel.

Measurements are usually made by wading, but may be made from the wagon bridge at high-water stages. The observations are taken once daily by Lloyd Jenkins, who lives in Julesburg. The gage rod consists of a 2 by 4 inch timber 7 feet long, spiked in a vertical position to a piling on the downstream side of the bridge, about 150 feet from the north end. No bench mark has been established, but the rod is securely spiked to the piling and any change in the position of the rod is hardly possible. The initial point for sounding is the left or north bank.

The following discharge measurements were made during 1902 by J. E. Field, S. G. Lees, and R. W. Hawley:

April 2: Gage height, 1.30 feet; discharge, 35 second-feet.
October 10: Gage height, 1.58 feet; discharge, 133 second-feet.
November 8: Gage height, 1.15 feet; discharge, 31 second-feet.

Daily gage height, in feet, of South Platte River at Julesburg, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
1	1.30	1.20	1.20	1.10	0.75	0.75	2.30	1.15	1.40
2	1.30	1.25	1.10	1.10	.75	.75	2.20	1.15	1.40
3	1.30	1.25	1.05	1.50	.75	.75	2.00	1.15	1.40
4	1.30	1.25	1.05	1.25	.80	.75	1.80	1.15	1.55
5	1.25	1.20	1.05	1.15	.80	.75	1.75	1.15	1.75
6	1.25	1.20	1.15	1.15	.80	.75	1.70	1.15	1.90
7	1.25	1.20	1.15	1.15	.75	.75	1.70	1.15	2.00
8	1.20	1.15	1.15	1.00	.75	.75	1.70	1.15	2.20
9	1.20	1.15	1.00	1.00	.75	.75	1.65	1.15	2.45
10	1.20	1.15	1.00	1.00	.75	.75	1.55	1.15	2.50
11	1.20	1.15	1.00	.90	.75	.75	1.50	1.15	2.50
12	1.20	1.30	1.60	.90	.75	.75	1.45	1.15	2.50
13	1.20	1.20	1.35	.90	.75	.75	1.40	1.15	2.60
14	1.45	1.20	1.25	.80	.75	.75	1.40	1.20	2.60
15	1.40	1.30	1.25	.80	.75	.75	1.35	1.20	2.60
16	1.30	1.25	1.20	.80	.75	.75	1.30	1.20	2.60
17	1.30	1.20	1.20	.80	.75	.75	1.25	1.20	2.60
18	1.25	1.15	1.10	.80	.70	.75	1.20	1.20	2.60
19	1.20	1.20	1.10	.80	.70	.75	1.20	1.20	2.70
20	1.20	1.30	1.10	.80	.70	.75	1.20	1.20	.....
21	1.25	1.20	1.10	.80	.80	1.20	1.20	1.20	2.75
22	1.30	1.15	1.00	.80	.80	1.90	1.25	1.20	2.80
23	1.40	1.15	1.00	.80	.80	1.90	1.25	1.20	2.80
24	1.30	1.10	.95	.80	.80	2.00	1.25	1.20	2.85
25	1.30	1.10	.95	.85	.80	2.00	1.20	1.20	2.90
26	1.25	1.25	.90	.85	.80	2.10	1.20	1.25	(a)
27	1.20	1.25	1.00	1.75	.80	2.20	1.20	1.30	.....
28	1.20	1.25	1.10	1.00	.80	2.30	1.20	1.40	.....
29	1.20	1.20	1.10	.80	.75	2.30	1.20	1.40	.....
30	1.20	1.25	1.10	.80	.75	2.30	1.15	1.40	.....
31	.....	1.25	.....	.75	.75	.....	1.15	.....	.....

a Frozen.

Rating table for South Platte River at Julesburg, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.8	4	1.4	75	2.0	407	2.6	953
.9	9	1.5	105	2.1	488	2.7	1,058
1.0	15	1.6	144	2.2	573	2.8	1,167
1.1	23	1.7	195	2.3	662	2.9	1,280
1.2	35	1.8	258	2.4	755		
1.3	52	1.9	330	2.5	852		

Estimated monthly discharge of South Platte River at Julesburg, Colo.

[Drainage area, 20,598 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
pril	89	35	46	2,737	0.0022	0.0025
ay	52	23	37	2,275	.0017	.0020
une	144	9	28	1,666	.0014	.0016
uly	225	2	19	1,168	.0010	.0012
ugust	4	0	3	184	.0001	.0001
eptember	662	2	153	9,104	.0074	.0083
ctober	662	28	129	7,932	.0063	.0073
ovember	75	28	37	2,202	.0018	.0020
ecember 1-25			761	37,736	.0369	.0343

MIDDLE CROW CREEK NEAR HECLA, WYO.

This station was established March 24, 1902, by A. J. Parshall. It s located 4 miles northwest of Hecla, Wyo., on a footbridge. The gage is attached to the timber of the bridge, and is graduated to hundredths of a foot. It is read twice daily by Hugh W. McGee. The nitial point for sounding is on the left bank. The channel is straight above the station and curved below. The right bank is low and subject to overflow. The left bank is high and does not overflow. The bed of the stream is sandy. The bench mark is a notch cut in a tree 5 feet east of the gage. Its elevation is 4.1 feet above the zero of the gage.

Discharge measurements of Middle Crow Creek near Hecla, Wyo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 24	A. J. Parshall	0.80	3
April 20	do	2.20	17
May 7	do	2.40	28
May 14	do	2.50	31
May 20	do	2.20	25
June 1	do	1.05	8

Daily gage height, in feet, of Middle Crow Creek near Hecla, Wyo.

Day.	April.	May.	June.	July.	Day.	April.	May.	June.	July.
1902.					1902.				
1	0.80	2.45	1.15	0.73	17	1.00	1.80	0.55	0.40
2	.80	2.35	1.05	.73	18	1.35	1.80	.55	.48
3	.80	2.50	.90	.65	19	1.75	2.05	.55	.68
4	.80	2.50	.90	.60	20	2.10	2.10	.55	.67
5	.80	2.45	.85	.50	21	2.30	1.70	.60	.68
6	.80	2.35	.85	.50	22	1.65	1.57	.55	.50
7	.90	2.35	.87	.48	23	1.25	1.50	.50	.50
8	.95	2.38	.82	.45	24	1.35	1.43	.45	.48
9	1.05	2.30	.75	.45	25	1.40	1.32	.32	.40
10	1.15	2.35	.70	.45	26	1.40	1.35	.30	.40
11	1.25	2.40	.60	.48	27	1.55	1.62	.35	.40
12	1.40	2.35	.60	.43	28	1.85	1.70	.70	.45
13	1.40	2.27	.58	.40	29	1.90	1.40	1.12	.40
14	1.35	2.40	.55	.40	30	2.40	1.35	.90	.35
15	1.25	2.40	.58	.40	31		1.20		.30
16	1.05	2.10	.60	.40					

Rating table for Middle Crow Creek near Hecla, Wyo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
.0		0.7	4.5	1.4	13.5	2.1	24.0
0.1	0.5	.8	5.5	1.5	15.0	2.2	25.5
.2	1.0	.9	6.5	1.6	16.5	2.3	27.0
.3	1.5	1.0	7.5	1.7	18.0	2.4	28.5
.4	2.0	1.1	9.0	1.8	19.5	2.5	30.0
.5	2.5	1.2	10.5	1.9	21.0	2.6	31.5
.6	3.5	1.3	12.0	2.0	22.5	2.7	33.0

Estimated monthly discharge of Middle Crow Creek near Hecla, Wyo.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
pril	28.5	5.5	12.6	750
ay	30.0	10.5	22.4	1,375
ne	9.8	1.5	4.4	263
ly	4.8	1.5	2.6	161

SOUTH PLATTE RIVER AT KERSEY, COLO.

This station was established April 27, 1901, at Kersey, a station on the Union Pacific Railroad, about 6 miles east of Greeley, at a bridge 1½ miles north of the railroad station itself. This station was intended to take the place of the one previously maintained at Orchard, Colo. This point was selected on account of the regularity of the channel and the fact that there was a wagon bridge crossing the river from which gagings could be made at high water. It is of particular value owing to the fact that the point is just below all the important tributaries of the South Platte, which derive their supply from the mountain region. It is also at about the point where water could be used to the best advantage for storage in reservoirs along South Platte River in northeastern Colorado. The observer is Edward K. Plumb, who lives near the bridge and reads the rod daily. The gage rod consists of a vertical 2 by 6 inch timber, 8 feet long, marked in feet and tenths and spiked to the downstream side of the third pile of the bridge from its south end. The initial point for soundings is the right bank, downstream side, the bridge being marked every 10 feet. The right bank is high and not liable to overflow, but the left is low and water spreads over a considerable distance at high stages.

The following discharge measurements were made during 1902 by J. E. Field and R. W. Hawley:

January 3: Gage height, 2.65 feet; discharge, 634 second-feet.
February 28: Gage height, 2.70 feet; discharge, 700 second-feet.
April 2: Gage height, 1.85 feet; discharge, 328 second-feet.
August 15: Gage height, 1.30 feet; discharge, 62 second-feet.
November 2: Gage height, 1.65 feet; discharge, 188 second-feet.

Daily gage height, in feet, of South Platte River at Kersey, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.85	3.50	2.70	1.85	1.10	1.60	2.50	1.30	1.30	2.00	1.75	2.50
2	2.85	3.50	2.65	1.85	1.10	1.50	1.60	1.30	1.40	2.00	1.80	2.30
3	2.85	3.50	2.65	1.85	1.10	1.50	1.50	1.30	1.40	2.00	1.80	2.30
4	2.85	3.50	2.65	1.85	1.50	1.40	1.50	1.30	1.40	2.00	1.80	2.30
5	2.75	3.20	2.65	1.85	1.75	1.40	1.40	1.30	1.40	2.00	1.80	2.30
6	2.75	2.90	2.60	1.75	1.50	40	1.40	1.30	1.40	2.00	1.80	2.30
7	2.70	2.70	2.60	1.75	1.20	1.40	1.40	1.30	1.40	2.00	1.80	2.30
8	2.70	2.65	2.60	1.60	1.20	40	1.50	1.30	1.40	1.95	1.80	2.30
9	2.65	2.60	2.60	1.60	1.20	40	1.60	1.30	1.40	1.95	1.80	2.30
10	2.60	2.60	2.55	1.55	1.20	40	1.60	1.30	1.40	1.95	1.80	2.30
11	2.60	2.60	2.55	1.50	1.30	40	1.80	1.30	1.40	1.95	1.80	2.30
12	2.60	2.70	2.50	1.45	1.30	40	1.60	1.30	1.40	1.95	1.80	2.30
13	2.55	2.75	2.50	1.40	1.30	1.40	1.50	1.30	1.40	1.90	1.80	2.30
14	2.55	2.90	2.40	1.35	1.30	1.40	1.40	1.30	1.40	1.80	1.80	2.35
15	2.50	2.80	2.30	1.30	1.30	1.35	1.40	1.30	1.40	1.75	1.80	2.35
16	2.50	2.80	2.30	1.25	1.30	1.30	1.30	1.30	1.40	1.75	1.80	2.40
17	2.50	2.80	2.25	1.25	1.30	1.30	1.30	1.30	1.40	1.65	1.80	2.45
18	2.50	2.80	2.25	1.25	1.30	1.30	1.30	1.30	1.40	1.60	1.90	2.50
19	2.50	2.80	2.25	1.20	1.30	1.30	1.30	1.30	40	1.60	2.00	2.50
20	2.50	2.80	2.20	1.20	1.40	1.30	1.30	1.30	40	1.60	2.20	2.50
21	2.60	2.80	2.15	1.20	1.40	1.30	1.30	1.30	40	1.65	2.40	2.50
22	2.60	2.80	2.10	1.10	1.40	1.30	1.30	1.30	4.50	1.65	2.40	2.60
23	2.60	2.80	2.00	1.10	1.40	1.30	1.30	1.30	4.00	1.70	2.35	2.60
24	2.65	2.75	2.00	1.10	1.40	1.30	1.30	1.30	3.50	1.70	2.30	2.60
25	2.85	2.75	2.00	1.10	1.40	1.30	1.30	1.40	2.40	1.70	2.30	2.55
26	3.50	2.70	2.00	1.10	1.40	1.35	1.30	1.40	2.00	1.70	2.30	2.55
27	3.50	2.70	2.00	1.10	1.40	1.35	1.30	1.40	2.00	1.70	2.30	2.55
28	3.50	2.70	1.90	1.10	1.45	1.35	1.30	1.40	2.20	1.70	2.30	2.50
29	3.50	.....	1.90	1.10	1.50	1.35	1.30	1.40	2.10	1.70	2.30	2.45
30	3.50	.....	1.90	1.10	1.50	3.75	1.30	1.40	2.00	1.70	2.30	2.40
31	3.50	.....	1.90	.....	1.60	.....	1.30	1.30	.....	1.75	.....	2.40

Rating table for South Platte River at Kersey, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	2	1.4	105	2.6	637	3.8	1,965
.4	4	1.6	170	2.8	770	4.0	2,261
.6	8	1.8	243	3.0	935	4.2	2,557
.8	14	2.0	325	3.2	1,139	4.4	2,853
1.0	29	2.2	423	3.4	1,386		
1.2	59	2.4	527	3.6	1,669		

Estimated monthly discharge of South Platte River at Kersey, Colo.

[Drainage area, 9,470 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches
1902.						
.....	1,524	580	836	51,404	0.0883	0.101
.....	1,524	637	862	47,873	.0910	.095
.....	700	282	486	29,883	.0513	.059
.....	262	42	122	7,259	.0129	.014
.....	224	42	96	5,903	.0111	.013
.....	1,891	80	158	9,402	.0167	.019
.....	580	80	124	7,624	.0131	.015
.....	105	80	85	5,226	.0090	.010
ber.....	2,631	80	363	21,600	.0383	.043
.....	325	170	249	15,310	.0263	.030
ber.....	527	224	334	19,874	.0353	.039
ber.....	637	475	532	32,711	.0562	.065
he year.....	2,631	42	354	254,069	.0375	.503

BIG THOMPSON CREEK NEAR ARKINS, COLO.

s stream drains the country immediately north of that drained headwaters of St. Vrain Creek, and is one of the largest tribu- of South Platte River, into which it empties about 4 miles the town of Evans. Little Thompson Creek is an important ary of Big Thompson Creek, and the country drained by these reams makes up irrigation district No. 4. The junction of these is near the lower end of the district, a short distance above the where their combined waters enter the South Platte.

ords of the flow of this stream were begun in April, 1888. The was established at its present location on April 1, 1899. The iversion above the gaging station is Handy ditch, a record of ge heights of which is kept by the water commissioner of that t, J. M. Wolaver, who also kept the records of Big Thompson at this point during the year 1900. It is necessary to include scharge of Handy ditch in order to obtain the total run-off of the The rod is a vertical 2-inch by 4-inch timber fastened to wnstream side of the right-hand end of the wagon bridge on the of John Chasteen. The bench mark is 25 feet south of the and is a nail in the root of a cottonwood stump, the head of il being 9.35 feet above the zero of the gage. The channel of ream is lined with bowlders and is very rough, but, not being

likely to change, it furnishes a good point for obtaining accura measurements. A permanent station could be located here to adva tage. Like the other tributaries of the South Platte, nearly all of t normal flow of Big Thompson and Little Thompson creeks is used f irrigation, and during the high-water stages the greater part of t volume is diverted into large reservoirs, from which it is used advantage later in the season.

The following discharge measurements were made during 1902 J. E. Field and M. C. Hinderlider:

August 30: Gage height, 0.75 feet; 86 second-feet.
November 14: Gage height, 0.42 feet; 28 second-feet.

Daily gage height, in feet, of Big Thompson Creek near Arkins, Colo.[a]

Day.	May.	June.	July.	Aug.	Sept.	Oc
1902.						
1	.....	2.10	1.40	0.80	0.60	
2	.....	2.00	1.20	.80	.60	
3	.....	1.80	1.30	.80	.60	
4	.....	2.00	1.30	.90	.60	
5	.....	2.20	1.20	.90	.50	
6	.....	2.00	1.10	.80	.50	
7	.....	2.00	1.00	.80	.50	
8	.....	2.20	1.00	.80	.50	
9	.....	2.20	.90	.80	.50	
10	.....	2.30	1.00	.70	.50	
11	.....	2.20	1.00	.70	.50	
12	.....	2.00	1.00	.70	.50	
13	.....	1.90	1.00	.70	.50	
14	.....	1.90	1.00	.80	.50	
15	.....	2.00	1.00	.80	.50	
16	.....	1.90	1.00	.70	.40	
17	.....	1.80	1.00	.70	.40	
18	.....	1.70	1.60	.70	.40	
19	.....	1.60	1.40	.70	.40	
20	.....	1.60	1.10	.70	.50	
21	.....	1.60	1.00	.60	1.00	
22	.....	1.60	1.00	.60	1.20	
23	.....	1.50	1.00	.70	1.10	
24	.....	1.60	1.00	.70	.90	
25	0.90	1.60	.90	.70	.80	
26	1.20	1.60	1.00	.60	1.10	
27	1.50	1.50	.90	.60	1.00	
28	2.00	1.60	.80	.60	.90	
29	1.60	1.70	.80	.60	.90	
30	2.00	1.50	.80	.70	.80	
31	2.10	.....	.80	.60	.....	

[a] To secure total discharge of Big Thompson Creek in figuring run-off, etc., add number of sec feet flowing in Handy Ditch for corresponding dates.

ating table for Big Thompson Creek near Arkins, Colo., for 190.?.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1	0.8	96	1.4	271	2.0	539
12	.9	118	1.5	310	2.1	593
26	1.0	143	1.6	350	2.2	650
41	1.1	172	1.7	393	2.3	710
58	1.2	203	1.8	439		
76	1.3	236	1.9	486		

ated monthly discharge of Big Thompson Creek near Arkins, Colo.[a]

[Drainage area, 305 square miles.]

h.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
.....	35	20	29	1,726	0.10	0.11
.....	659	80	299	18,385	.98	1.13
.....	773	310	505	30,050	1.66	1.85
.....	385	108	182	11,191	.60	.69
.....	130	67	90	5,534	.30	.35
.....	238	34	89	5,296	.29	.32
.....	198	46	98	6,026	.32	.37

[a] The discharge of Handy Ditch is included.

ST. VRAIN CREEK AT LYONS, COLO.

n of Lyons is situated between the north and south forks in Creek, the forks uniting at a point about 1 mile east of the he town. Records of the flow of the creek at or near Lyons kept since April, 1888, except during the years 1893 and the station was not put in its present condition until May 5, which date records have been kept throughout each irri- son. The present station is located one-half mile southeast Colo., below the junction of the north and south forks of Creek. The supply ditch takes water out on the left side eam above the gage. To obtain the total run-off of the asin of the creek at this station, the amount of water in the be added to the discharge of the creek. The gage is an by 4 inch timber, graduated to vertical tenths of a foot,

the space between the marks being 0.134 of a foot. It is fastened to posts driven into the ground. The right bank of the stream is low and liable to overflow. The left bank is a railroad embankment and is not liable to overflow. Measurements are usually made by wading, but at high water they can be made from a wagon bridge 400 feet below the gage. The bench mark is a spike driven into the root of a large cottonwood tree, 150 feet north of the gage rod. The head of the spike is 6.51 feet above gage datum. The observer during 1902 was L. H. Dickson, commissioner of the St. Vrain water district, who read the gage during the irrigation season.

During 1902 the following discharge measurements were made by J. E. Field and M. C. Hinderlider:

July 28: Gage height, 2.50 feet; discharge, 91 second-feet.
August 30: Gage height, 2.05 feet; discharge, 31 second-feet.
November 8: Gage height, 2.08 feet; discharge, 40 second-feet.

Daily gage height, in feet, of St. Vrain Creek at Lyons, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	1.60	2.35	3.35	2.72	2.32	2.18	2.45	2.08
2	1.60	2.40	3.15	2.70	2.30	2.10	2.50	2.08
3	1.70	2.50	3.10	2.75	2.45	2.10	2.50	2.08
4	1.82	2.50	3.28	2.67	2.50	2.10	2.50	2.08
5	1.80	2.55	3.32	2.70	2.42	2.05	2.50	2.08
6	1.85	2.55	3.30	2.60	2.45	2.02	2.50	2.08
7	1.90	2.58	3.35	2.50	2.30	2.00	2.40	.....
8	2.00	2.70	3.45	2.45	2.35	2.00	2.35	.....
9	2.10	2.80	3.55	2.51	2.25	2.00	2.30	.....
10	2.00	2.90	3.45	2.58	2.20	2.00	2.30	.....
11	1.80	3.10	3.35	2.56	2.18	2.00	2.40	.....
12	1.80	3.20	3.35	2.51	2.18	2.03	2.35	.....
13	1.85	3.20	3.30	2.47	2.18	2.00	2.35	.....
14	1.90	3.25	3.30	2.50	2.20	2.00	2.35	.....
15	1.80	3.35	3.38	2.53	2.20	1.95	2.30	.....
16	1.85	3.22	3.25	2.54	2.20	1.95	2.25	.....
17	1.95	3.18	3.22	2.64	2.30	1.95	2.25	.....
18	2.00	3.10	3.15	2.80	2.20	1.95	2.22	.....
19	2.10	2.90	3.20	2.80	2.15	1.95	2.20	.....
20	2.15	2.85	3.20	2.60	2.12	1.95	2.15	.....
21	2.25	2.70	2.95	2.52	2.10	2.30	2.12	.....
22	2.10	2.60	2.95	2.50	2.10	3.00	2.15	.....
23	2.05	2.55	2.92	2.48	2.15	2.95	2.10	.....
24	2.07	2.55	2.98	2.43	2.18	2.55	2.20	.....
25	2.05	2.60	2.92	2.48	2.18	2.55	2.20	.....
26	2.07	3.00	2.95	2.50	2.08	2.60	2.10	.....
27	2.05	3.20	2.92	2.52	2.18	2.40	2.10	.....
28	2.15	3.20	2.95	2.45	2.10	2.40	2.10	.....
29	2.25	3.10	3.00	2.32	2.10	2.55	2.08	.....
30	2.25	3.30	2.78	2.50	2.05	2.50	2.05	.....
31	.....	3.50	.....	2.25	2.25	.....	2.05	.....

Daily gage height, in feet, of Supply ditch at Lyons, Colo.[a]

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	0.21	0.25	1.30	0.65	0.55	0.25	0.40	0.40
2	.21	.25	1.35	.60	.25	.25	.40	.40
3	.23	.25	.92	.65	.25	.25	.50	.40
4	.25	.25	.50	.70	.25	.25	.50	.25
5	.25	.25	.68	.25	.25	.25	.50	.25
6	.25	.25	.72	.25	.25	.25	.50	.25
7	.25	.20	.70	.25	.25	.20	.50	.25
8	.25	.20	.75	.25	.25	.20	.40	.25
9	.25	.25	.85	.25	.35	.20	.40	.25
10	.41	.25	.85	.25	.45	.20	.40	.25
11	.25	.45	.70	.38	.45	.25	.40	.25
12	.25	.45	.55	.48	.45	.25	.40	.25
13	.25	.70	.50	.45	.45	.25	.40	.25
14	.25	.70	.50	.45	.35	.25	.40	.25
15	.25	.80	.82	.25	.25	.25	.40	.25
16	.25	.80	.80	.25	.25	.25	.40	.25
17	.25	.80	.75	.25	.25	.25	.40	.25
18	.25	.80	.75	.25	.25	.25	.40	.25
19	.25	.80	.75	.25	.25	.25	.40	.25
20	.25	.50	.70	.25	.25	.25	.40	.....
21	.25	.50	.70	.25	.25	.25	.40	.....
22	.25	.50	.70	.40	.25	.25	.50	.....
23	.25	.45	.55	.40	.25	.60	.20	.....
24	.25	.45	.50	.40	.25	.60	.20	.....
25	.25	.45	.50	.25	.25	.50	.40	.....
26	.25	.20	.50	.25	.40	.40	.40	.....
27	.25	.60	.40	.25	.45	.40	.40	.....
28	.25	.80	.30	.40	.40	.40	.40	.....
29	.25	.80	.25	.55	.40	.40	.40	.....
30	.25	.80	.25	.68	.40	.40	.40	.....
31	.....	1.20	.....	.50	.45	.....	.40	.....

[a] The daily flow of Supply ditch to be added to St. Vrain Creek at gaging station to give total discharge of St. Vrain Creek used in working up run-off, etc.

Rating table for St. Vrain Creek at Lyons, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.1	1	1.8	18	2.5	91	3.2	280
1.2	2	1.9	24	2.6	109	3.3	321
1.3	3	2.0	31	2.7	130	3.4	365
1.4	4	2.1	39	2.8	153	3.5	413
1.5	6	2.2	48	2.9	180	3.6	463
1.6	9	2.3	59	3.0	211	3.7	514
1.7	13	2.4	74	3.1	245	3.8	569

Estimated monthly discharge of St. Vrain Creek at Lyons, Colo.[a]

[Drainage area, 209 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	57	12	34	2,023	0.16	0.
May	500	70	215	13,220	1.03	1.
June	485	152	312	18,565	1.49	1.
July	167	69	112	6,887	.54	.
August	95	43	59	3,628	.28	.
September	329	31	74	4,403	.35	.
October	107	42	69	4,243	.33	.
November 1–19	.....	.....	84	3,165	.40	.

[a] This includes the flow of the supply ditch.

CLEAR CREEK AT FORKSCREEK, COLO.

The gaging station is located at the Forkscreek railroad station c the Colorado and Southern Railway, in Clear Creek canyon, just belo the junction of the North and South Forks of Clear Creek. It w established May 29, 1899, and has been continued through the irrig tion seasons of 1899, 1900, 1901, and 1902. The gage consists of weight fastened to a wire running over a pulley fastened to the wa at the railway station. Bench mark No. 1 is a point on the timber t which the pulley is attached, and is 13.58 feet above gage datun Bench mark No. 2 is a granite point 49.5 feet east of the first benc mark, and is 15.46 feet above gage datum. In May, 1902, a trussed fo bridge 48 feet long was placed across the creek at right angles to t direction of the current just below the railway bridge and about 3 feet below the forks of the creek. This bridge is located over t most desirable cross section of the stream, and where satisfacto measurements can be made. It is possible to secure fairly good resu by means of measurements made at two bridges above the forks. low water the stream is gaged by wading. The stream flows rapic through this part of the canyon, the channel being rocky and the f great. Both banks are high and rocky. The observer is C. A. Jon

The following discharge measurements were made during 1902 S. G. Lees and M. C. Hinderlider:

June 14: Gage height, 2.90 feet; discharge, 655 second-feet.
September 10: Gage height, 1.50 feet; discharge, 60 second-feet.
September 20: Gage height, 1.60 feet; discharge, 55 second-feet.
October 15: Gage height, 1.80 feet; discharge, 82 second-feet.

Daily gage height, in feet, of Clear Creek at Forksreek, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
.....	.....	2.10	3.05	2.60	1.90	1.60	1.80
.....	.....	2.20	2.95	2.60	1.90	1.70	1.80
.....	.....	2.40	2.95	2.55	1.90	1.70	1.80
.....	.....	2.40	2.95	2.50	1.90	1.60	1.80
.....	.....	2.30	3.00	2.50	1.90	1.60	1.75
.....	.....	2.55	3.00	2.45	1.90	1.50	1.70
.....	.....	2.60	3.00	2.40	1.90	1.50	1.70
.....	.....	2.65	3.05	2.30	1.90	1.50	1.70
.....	.....	2.65	3.15	2.30	1.80	1.50	1.70
.....	.....	2.70	3.15	2.30	1.85	1.50	1.70
.....	.....	2.75	3.30	2.25	1.90	1.55	1.70
.....	.....	2.75	3.05	2.30	1.90	1.60	1.70
.....	1.65	2.70	2.95	2.20	1.90	1.60	1.60
.....	1.65	2.77	2.95	2.15	1.90	1.55	1.70
.....	1.65	2.80	2.95	2.15	1.80	1.65	1.70
.....	1.75	2.90	2.90	2.35	1.80	1.60	1.70
.....	1.70	2.90	2.85	2.40	1.80	1.55	1.70
.....	1.75	2.70	2.78	2.40	1.80	1.55	1.60
.....	1.80	2.75	2.75	2.30	1.75	1.60	1.60
.....	.....	2.65	2.75	2.30	1.70	1.65	1.60
.....	.....	2.70	2.75	2.20	1.60	2.05	1.60
.....	.....	2.55	2.70	2.10	1.60	1.90	1.60
.....	.....	2.55	2.70	2.10	1.65	1.75	1.60
.....	.....	2.40	2.65	2.10	1.80	1.75	1.60
.....	.....	2.55	2.65	2.10	1.80	1.80	1.60
.....	.....	2.70	2.60	2.10	1.80	1.75	1.60
.....	1.60	2.95	2.70	2.10	1.80	1.70	1.60
.....	1.70	2.75	2.75	2.05	1.70	1.70	1.60
.....	1.75	2.80	2.75	2.00	1.70	1.90	1.50
.....	2.05	2.80	2.60	2.00	1.70	1.80	.....
.....	.....	2.90	.....	2.00	1.65	.....	.....

Rating table for Clear Creek at Forksreek, Colo., for 1902.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
20	2.2	179	3.1	480	4.0	946
32	2.3	205	3.2	522	4.1	1,003
44	2.4	235	3.3	566	4.2	1,060
58	2.5	267	3.4	614	4.3	1,117
75	2.6	299	3.5	665	4.4	1,174
93	2.7	332	3.6	719	4.5	1,231
112	2.8	367	3.7	775	4.6	1,288
133	2.9	403	3.8	832	4.7	1,345
155	3.0	441	3.9	889	4.8	1,402

Estimated monthly discharge of Clear Creek at Forkscreek, Colo.

[Drainage area, 345 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April 13–19, 27–30	.....	.....	81	1,766	0.23	0.09
May	422	155	315	19,369	.91	1.05
June	566	299	398	23,683	1.15	1.28
July	299	133	199	12,236	.58	.67
August	112	58	94	5,780	.27	.31
September	144	44	69	4,106	.20	.22
October 1–29	.....	.....	70	4,026	.20	.22

SOUTH PLATTE RIVER AT DENVER, COLO.

In the spring of 1895 a river station was established at the Twenty-third Street Viaduct in the city of Denver, but observations were discontinued on June 18, as the location was found to be unfavorable for accurate measurements, and the water had fallen below the gage. In July a station was established at the Fifteenth Street Bridge and observations were begun, these being made in the morning and in the afternoon. Stream measurements are made from the lower side of the bridge. The original gage consisted of two 6 by 2 inch timbers spiked together, inclined and graduated to vertical tenths of a foot. The space between the marks was 0.156 foot. The timbers were fastened to posts driven into the bank. The bench mark is 107 feet southwest from the gage and is a cross mark on top of the east abutment of the Fifteenth Street Bridge on the north corner. It is marked B. M. and is 6.15 feet above the 9-foot mark of the gage rod.

Another inclined gage rod reading the same as the one on the right bank was placed on the left side in August, 1898. It consisted of a 4 by 4 inch by 12-foot timber fastened to posts driven into the left bank and graduated to vertical feet and tenths.

This rod was washed out by the high water of June, 1900, which also removed the sand bar in front of the rod on the right-hand side, making it available at low-water stages, and since that time the readings have been taken from the latter rod.

The initial point for soundings is on the right bank at the post of the iron railing. The channel is straight for about 1,000 feet above and below and the water moves with moderate velocity. The bed of the stream is sandy and shifting. This point is immediately below the

mouth of Cherry Creek, which enters between the Fourteenth Street and Fifteenth Street bridges. The stream at this point is confined between artificial embankments of furnace slag.

May 15, 1901, a T-rail was placed on the site of the latter rod, which was stolen. The rail was embedded in an inclined position in the slag bank. The zero of the rod is 12 feet below the top of the capstone of the southeast abutment of the Sixteenth Street Viaduct 100 feet northeast of the rod. All readings were taken from this rod from May 15, 1901, to June 9, 1903, when the rod was again stolen. On June 10, 1903, a vertical 4 by 4 inch timber was placed at the same point and fastened to a cottonwood tree. The zero of the rod was placed at the same elevation as the zero of the old gage. The observer is J. A. Banning, water commissioner.

Discharge measurements of South Platte River at Denver, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
April 1	J. E. Field	1.10	107
May 15	do	1.65	241
May 29	do	2.22	557
June 10	S. G. Lees	1.00	74
June 11	do	.98	62
June 12	do	1.05	68
June 13	do	1.85	163
June 16	do	1.00	63
July 16[a]	do	1.09	18
July 22	do	1.13	32
September 9	M. C. Hinderlider	1.10	22
September 12	do	1.00	16
October 14	do	1.30	63
October 28	R. W. Hawley	1.19	48
October 29	do	1.12	42

[a] Channel changed.

Daily gage height, in feet, of South Platte River at Denver, Colo.

Day.	Apr.	Oct.	Nov.	Dec.	Day.	Apr.	Oct.	Nov.	Dec.
1902.					1902.				
1	1.10	.....	1.20	.....	17	1.05	1.30	.....	1.1
2	1.09	.....	1.20	.....	18	1.00	1.30	.....	1.0
3	1.10	.....	1.20	.....	19	1.04	1.20	.....	1.0
4	1.02	.....	1.20	.....	20	.....	1.30	.....	1.2
5	1.04	.....	1.10	.....	21	.....	1.30	.....	1.4
6	1.16	1.22	1.10	.....	22	.....	1.30	.....	1.1
7	1.00	1.24	1.00	.....	23	.....	1.30	.....	1.2
8	.95	1.24	1.00	1.40	24	.....	1.20	.....	1.2
9	1.02	1.21	1.20	1.25	25	.....	1.20	.....	1.3
10	1.05	.....	1.10	1.20	26	.....	1.20	.....	1.3
11	1.02	.....	1.00	1.30	27	.....	1.20	.....	1.4
12	1.07	.....	1.00	1.12	28	.....	1.20	.....	1.4
13	1.08	.....	1.00	1.20	29	.....	1.20	.....	1.1
14	1.08	1.30	1.00	1.20	30	.....	1.20	.....	1.1
15	1.08	1.25	1.20	1.15	31	.....	1.20	.....	1.1
16	1.07	1.30	.....	1.10					

Rating table for South Platte River at Denver, Colo., for 1902.

JANUARY 1 TO JUNE 30, 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.6	2	0.9	48	1.2	106	1.5	187
.7	16	1.0	64	1.3	130	1.6	224
.8	32	1.1	83	1.4	156	1.7	270

JULY 1 TO DECEMBER 31, 1902.

0.8	2	1.2	56	1.6	221	2.0	435
.9	6	1.3	90	1.7	270	2.1	491
1.0	13	1.4	131	1.8	323	2.2	547
1.1	30	1.5	174	1.9	379		

Estimated monthly discharge of South Platte River at Denver, Colo.

[Drainage area, 3,840 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April 1–19	.....	.....	74	2,789	0.019	0.0
October 6–31	.....	.....	71	3,661	.018	.0
November 1–15	.....	.....	32	952	.008	.0
December 8–31	.....	.....	61	3,046	.016	.0

BEAR CREEK NEAR MORRISON, COLO.

Bear Creek is one of the smaller tributaries of the South Platte, heading in the vicinity of Mount Evans, about 30 miles southwest of Denver, and entering the main stream about 8 miles above that city. Although usually of small volume, the stream drains a considerable portion of very mountainous country, which is subject to more or less violent cloudbursts, so that floods sometimes come down this creek, causing great destruction to property and even loss of life. All of the normal flow of the stream is used for irrigation, and it is only during high-water stages that a large amount of water passes through it. Records of its flow have been kept for a portion of each irrigation season since April, 1888, with the exception of the years 1892, 1893, and 1894. The present station was established April 1, 1899. It is located just above the town of Morrison. The gage rod, which is a 2-inch by 6-inch timber placed vertically and marked in feet and tenths, is fastened to the upper side of the dam which diverts water into the mains of the Denver Union Water Company. The bench mark is the top of a granite bowlder about 100 feet above the rod on the left-hand side of the stream, and it is 10.33 feet above the gage datum. As in previous years, the station was maintained through cooperation with the Denver Union Water Company. The observer is S. Hebrew, an employee of the Denver Union Water Company.

Observations at this station were discontinued in March, 1902, sufficient data having been secured since its establishment in 1888.

Daily gage height, in feet, of Bear Creek near Morrison, Colo.

Day.	Feb.	Day.	Feb.	Day.	Feb.	Day.	Feb.
1902.		1902.		1902.		1902.	
1	0.75	8	0.95	15	1.15	22	1.15
2	.75	9	.95	16	1.25	23	1.15
3	.80	10	1.05	17	1.20	24	1.25
4	.75	11	1.05	18	1.25	25	1.30
5	.85	12	1.05	19	1.35	26	1.35
6	.85	13	.95	20	1.25	27	1.45
7	.90	14	.92	21	1.20	28	1.45

SOUTH PLATTE RIVER AT SOUTH PLATTE, COLO.

This station is located at the junction of the North and South forks of the South Platte River at the town of South Platte, on the Colorado and Southern Railroad, about 9 miles above the mouth of the canyon. The station was established March 28, 1902, by John E. Field, at the wagon bridge crossing the main stream about 150 feet below the junction of the two forks. This station is of special importance, its location being above the diverting gates of all irrigating

ditches and also above the intake of the Denver Union Water Company, which derives the greater part of its supply of water from the South Platte River a few miles below this station. The location of the Cheesman Storage Reservoir on the South Fork, 20 miles above this station, and the contemplated installation of large power plants on the two forks above, also add to the importance of this station as a point from which to secure data. Bridges across either fork above the main station allow of measurements being made on these streams, thereby checking all gagings on the main stream below.

The gagings on the main stream are made at high water from a wooden wagon bridge 76 feet long, and at low water by wading. The channel at this point is composed of bowlders and gravel and is reasonably stable. The right bank is the mountain side, rising directly from the bed of the stream at a slope of about 45 degrees. The left bank is low and covered with trees, and liable to overflow at very high water. The gage rod consists of a 2 by 4 inch timber 7 feet long, spiked in a vertical position to the upstream face of the timber pier in the middle of the river; the bench mark, which is a nail driven into the cap timber of the pier just above the rod, is 10.15 feet above the zero of the rod. Observations have been made twice daily during the irrigating season since the establishment of the station. The observer during the summer of 1902 was John B. Sevan. This station is located only about 200 feet from the Colorado and Southern Railway station, and is easily accessible from Denver.

Discharge measurements of South Platte River at South Platte, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 28	J. E. Field	1.85	145
May 2	do	2.00	208
June 13	S. G. Lees	1.87	167
July 17	do	1.00	53
Do	do	1.04	60
August 12	do	1.00	53
August 25	J. E. Field	1.55	122
September 7	M. C. Hinderlider	1.20	69
September 8	J. E. Field	1.20	69
September 13	M. C. Hinderlider	1.25	79
September 23	do	1.45	108
October 17	S. G. Lees	1.20	60
October 27	R. W. Hawley	1.18	57

Daily gage height, in feet, of South Platte River at South Platte, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
.....	1.72	1.11	2.50	1.55	1.00	1.20	1.20	0.95
.....	1.72	1.56	2.15	1.50	1.00	1.20	1.30	.95
.....	1.60	2.00	1.56	1.50	1.00	1.20	1.20	.97
.....	1.55	1.55	1.56	1.50	.56	1.25	1.10	.97
.....	1.55	1.55	1.56	1.40	1.25	1.20	1.10	.97
.....	1.72	1.55	1.55	1.35	1.60	1.30	1.20	.85
.....	1.82	1.55	1.56	1.30	1.30	1.30	1.10	.85
.....	2.12	1.56	1.55	1.30	1.20	1.30	1.10	.90
.....	3.30	1.11	1.56	1.30	1.10	1.40	1.10	.95
.....	2.80	1.55	1.10	1.40	1.10	1.30	1.00	1.02
.....	2.95	1.65	1.57	1.25	1.10	1.30	1.00	1.02
.....	2.40	2.15	1.10	1.35	1.00	1.22	1.20	.....
.....	2.80	2.15	1.50	1.35	1.05	1.25	1.20	.....
.....	2.90	2.15	1.45	1.25	1.00	1.30	1.10	.....
.....	2.85	2.15	1.50	1.15	1.15	1.30	1.10	.....
.....	2.45	2.15	1.50	1.00	1.30	1.30	1.10	.....
.....	2.25	2.15	1.45	1.35	1.40	1.20	1.10	.....
.....	2.20	2.10	1.45	1.40	1.40	1.20	1.10	.....
.....	2.20	2.05	1.45	1.40	1.40	1.20	1.00	.....
.....	2.30	1.55	1.45	1.35	1.40	1.30	1.00	.....
.....	2.30	1.10	1.80	1.25	1.40	1.40	1.00	.....
.....	3.25	1.90	1.75	1.20	1.60	1.60	1.00	.....
.....	2.00	1.85	1.60	1.25	1.60	1.35	.95	.....
.....	1.90	1.80	1.60	1.20	1.20	1.25	.90	.....
.....	1.90	1.75	1.55	1.20	1.20	1.15	.90	.....
.....	1.90	1.45	1.50	1.20	1.40	1.10	1.02	.....
.....	1.90	2.25	1.55	1.20	1.40	1.10	1.02	.....
.....	1.90	2.40	1.50	1.15	1.40	1.15	.95	.....
.....	1.82	2.65	1.85	1.15	1.35	1.20	.98	.....
.....	1.90	2.55	1.65	1.10	1.20	1.20	1.02	.....
.....	.....	2.45	.....	1.00	1.25	.....	1.02	.....

Rating table for South Platte River at South Platte, Colo., for 1902.

t.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2	5	1.0	55	1.8	160	2.6	348
3	8	1.1	65	1.9	178	2.7	380
4	12	1.2	75	2.0	197	2.8	414
5	18	1.3	86	2.1	218	2.9	449
6	24	1.4	98	2.2	240	3.0	485
7	30	1.5	112	2.3	264	3.1	521
8	36	1.6	127	2.4	290	3.2	557
9	45	1.7	143	2.5	318	3.3	593

Estimated monthly discharge of South Platte River at South Platte, Colo.

[Drainage area, 2,612 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep in
1902.						
April	593	119	260	15,471	0.100	
May	364	65	180	11,068	.069	
June	318	65	127	7,557	.049	
July	119	55	85	5,226	.033	
August	127	21	81	4,980	.031	
September	127	65	82	4,879	.031	
October	86	45	61	3,750	.023	
November 1–11			49	1,069	.019	

Miscellaneous measurements in Platte River drainage basin.

[Made by H. O. Su[illegible], B. E. Forbes, J. C. Stevens, Frank Dobson, Adna Dobson, R. H. Will

NEBRASKA.

Date.	Stream.	Locality.	D cha
1902.			Sec
July 5	Buffalo Creek	Sec. 33, T. 9, R. 18	
Do	do	Sec. 30, T. 10, R. 20	
March 25	Calamus	Burwell	
March 21	Elkhorn River, North Fork.	Norfolk	
April 13	do	do	
May 12	do	do	
June 16	do	do	
July 26	do	do	
August 22	do	do	
September 29	do	do	
November 14	do	do	
March 25	Loup, North	Burwell	1,
March 23	do	St. Paul	1,
Do	Loup, Middle	do	1,
September 7	Platte River	Kearney	
August 26	Platte River, North	Sec. 3, T. 23, R. 58 W., State line.	
August 28	do	do	
September 8	do	do	
September 22	do	do	

Miscellaneous measurements in Platte River drainage basin—Continued.

NEBRASKA—Continued.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
April 9	Platte River, South	North Platte	Dry.
May 20	do	do	207
July 7	Salt Creek	Lincoln	[a]5,438
July 10	do	do	[a]10,136
October 1	do	do	92
August 18	Spring Creek	Sec. 30, T. 10, R. 21 W	1.0
April 23	do	Sec. 36, T. 14, R. 47 W	2.4
May 7	do	Sec. 30, T. 15, R. 37 W	2.5
September 7	Wood River	Sec. 12, T. 9, R. 16 W	27.3
July 17	Blue Creek	Sec. 6, T. 16, R. 42 W	90
August 18	do	Sec. 19, T. 16, R. 42 W	50
July 22	Lawrence Fork	Sec. 36, T. 19, R. 52 W	1.4
Do	do	Sec. 11, T. 18, R. 52 W	1.6
July 29	do	Sec. 1, T. 18, R. 52 W	2.9
July 31	do	Sec. 15, T. 18, R. 52 W	2.2
August 18	Lonergan Creek	Sec. 19, T. 15, R. 39 W	2.5
August 19	Sand Creek	Sec. 14, T. 15, R. 40 W	1.3
May 7	White Tail Creek	S. line sec. 36, T. 15, R. 38 W.	24.7
Do	do	N. line sec. 36, T. 15, R. 38 W.	36.0
Do	do	NE. ¼ sec. 26, T. 15, R. 38 W.	33.0
April 13	Lodge Pole	Sec. 36, T. 14, R. 47 W	4.0
April 25	do	Sec. 35, T. 15, R. 55 W	12.0
June 2	do	Kimball	5.6
July 2	do	Sec. 25, T. 15, R. 56 W	7.5
Do	do	Sec. 31, T. 15, R. 56 W	10.5

[a] Flood.

Miscellaneous measurements in the Platte drainage.

[Made by A. J. Parshall and W. P. Edwards.]

Date.	Stream.	Locality.
1902.		
September 11	North Platte River	Saratoga
September 12	do	At mouth of Brush Creek
September 14	do	Fort Steele
September 24	do	do
September 26	do	Big Bend
September 29	do	North of Seminole Mountains.
October 1	do	South of Seminole Mountains.
September 12	Brush Creek, Carbon County, Wyo.	At mouth
Do	Grand Encampment Creek, Carbon County, Wyo.	Near mouth
September 13	Cow Creek, Carbon County, Wyo.	do
September 14	Pass Creek, Carbon County, Wyo.	do
September 29	Medicine Bow River, Carbon County, Wyo.	do
January 1	South Fork, Crow Creek	Granite Canyon, Laramie County, Wyo.
January 8	Clear Creek (tributary Crow Creek).	Reis Springs, Laramie County, Wyo.
Do	do	Corlett, Laramie County, Wyo.
Do	North Fork, Clear Creek (tributary Crow Creek).	do
January 15	Middle Crow	Simmons, Laramie County, Wyo.
March 12	do	At dam site, Laramie County, Wyo.
July 8	Bear Creek	Morrison
July 9	North Turkey Creek	Near Conifer
Do	Elk Creek	Winston
Do	Deer Park Creek	Bailey
Do	North Fork South Platte	do
July 10	Halls Gulch	Webster
Do	Jefferson Creek	Jefferson
Do	Michigan Creek	Como
Do	Tarryall Creek	Near Como
Do	Middle Fork South Platte River.	Fairplay
July 11	Fourmile Creek	Near Fairplay
Do	South Fork South Platte River.	Near Buffalo Springs

KANSAS RIVER DRAINAGE BASIN.

The drainage basin of the Kansas River lies between those of the latte and Arkansas rivers, being entirely within the region of the reat Plains, and principally within the arid or semiarid area. It has o mountain tributaries, but depends entirely for its water supply pon the water which, falling within or near the basin, percolates lowly to the drainage channels. The catchment area extends from astern Colorado to the Missouri River, a distance from east to west f 485 miles. Its extreme width is about 200 miles. The main stream f the Kansas River is formed at Junction, Kans., by the Republican nd Smoky Hill rivers, and flows east into the Missouri at Kansas ity. The Republican is its principal tributary and drains southern ebraska and northern Kansas by means of many small tributary eeks. The Solomon, Saline, and Smoky Hill rivers drain the plains northwestern Kansas. The Blue River is a small tributary in rtheastern Kansas, flowing south into the Kansas River, near Manttan, Kans. The following is a list of the stations in the Kansas ver drainage basin:

Kansas River at Lecompton, Kans.
Blue River near Manhattan, Kans.
Republican River at Junction, Kans.
Republican River and the Mill Race near Superior, Nebr.
Solomon River at Niles, Kans.
Saline River near Salina, Kans.
Smoky Hill River at Ellsworth, Kans.

KANSAS RIVER AT LECOMPTON, KANS.

The gaging station at Lecompton was established April 16, 1899, at new wagon bridge. On June 24, 1900, a new gage was established, e old gage having been broken. The present gage, a pine board 1 ch by 1 inch by 10 feet long, graduated to feet and tenths, is spiked top of the old gage, and is at the same elevation. On October 26, 900, a bench mark was established on top of the bottom flange of the on strut connecting the two iron cylinders at the south end of the ighway bridge over the river. The bench mark is at the west end of he strut, next to the cylinder. Its elevation is 12.19 feet above the ero of the gage. The observer is A. D. McAdow.

Discharge measurements of Kansas River at Lecompton, Kans.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 28	W. G. Russell	3.00	1,3[illegible]
May 28	do	7.00	14,31[illegible]
June 9	do	8.25	17,18[illegible]
June 21	do	6.50	13,14[illegible]
July 12	do	16.35	72,17[illegible]
July 30	do	6.15	12,87[illegible]
August 27	do	7.70	17,7[illegible]

Daily gage height, in feet, of Kansas River at Lecompton, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.10	2.20	2.00	3.40	2.90	7.25	10.95	8.00	14.45	7.60	5.60	5.80
2	2.10	2.20	2.00	3.40	2.90	7.50	11.30	7.55	12.85	7.50	5.60	5.80
3	2.10	2.20	2.00	3.35	2.90	7.00	11.75	7.10	11.35	9.35	5.60	5.75
4	2.10	2.20	1.90	3.30	2.90	6.60	11.95	6.55	9.90	11.20	5.60	5.70
5	2.10	2.20	1.90	3.20	2.90	7.20	12.20	5.50	8.95	13.05	5.60	5.70
6	2.10	2.20	1.80	3.20	3.05	7.70	12.50	5.30	8.50	12.40	5.60	5.70
7	2.20	2.20	2.20	3.20	3.35	9.00	12.85	4.90	7.90	10.20	5.60	5.70
8	2.30	2.20	2.65	3.20	3.65	8.50	13.20	4.70	7.45	9.90	5.60	5.70
9	2.40	2.20	2.85	3.20	3.80	7.95	13.80	4.60	6.90	9.55	5.60	5.65
10	2.40	2.20	3.15	3.10	3.75	9.50	14.60	4.90	6.60	8.70	5.60	5.60
11	2.40	2.20	3.40	3.10	3.70	9.60	15.30	5.40	6.10	7.65	5.50	5.60
12	2.40	2.20	3.35	3.10	3.75	9.20	16.30	4.95	5.20	7.65	5.55	5.55
13	2.40	2.20	3.20	3.10	3.95	8.50	16.85	4.90	4.70	8.20	5.70	5.50
14	2.40	2.10	3.00	3.10	4.25	7.80	17.40	4.85	4.30	9.75	5.90	5.50
15	2.35	2.10	3.00	3.10	4.50	7.50	17.60	4.80	4.30	9.30	6.00	5.50
16	2.30	2.10	3.50	3.10	4.90	7.25	16.65	4.80	4.30	8.55	6.00	5.40
17	2.30	2.10	3.50	3.10	4.90	6.90	15.55	4.70	4.25	7.90	6.10	5.40
18	2.30	2.10	3.40	3.05	4.70	6.70	13.50	4.65	4.20	7.35	6.40	5.50
19	2.30	2.10	3.40	3.00	4.95	6.50	11.50	4.60	4.15	6.90	6.65	5.90
20	2.30	2.00	3.40	3.00	5.40	6.45	12.80	4.50	4.10	6.45	6.50	6.60
21	2.30	2.00	3.30	3.00	5.70	6.65	10.60	5.15	4.10	6.05	6.40	7.00
22	2.30	2.00	3.30	3.00	6.20	8.80	8.60	5.55	4.30	6.00	6.20	7.25
23	2.30	2.10	3.50	3.00	6.70	8.45	7.00	6.75	5.80	5.90	6.20	7.40
24	2.30	2.10	3.50	3.00	7.10	7.70	7.30	6.60	6.20	5.70	6.20	7.35
25	2.30	2.10	3.40	3.00	7.75	7.15	7.05	6.50	6.40	5.60	6.15	7.25
26	2.30	2.00	3.40	3.00	8.40	6.70	7.00	6.85	6.65	5.60	6.10	7.30
27	2.30	2.00	3.30	3.00	9.45	6.35	7.00	7.75	6.90	5.60	6.05	7.10
28	2.30	2.00	3.30	3.00	9.25	6.00	6.80	8.00	8.30	5.50	6.00	7.00
29	2.30	.....	3.30	5.00	7.60	9.00	6.35	8.20	8.80	5.40	6.00	7.00
30	2.30	.....	3.30	2.95	5.65	10.70	6.10	8.85	7.90	5.40	5.80	7.00
31	2.20	.....	3.30	.....	5.55	.....	7.15	12.85	.....	5.40	.....	6.90

Rating table for Kansas River at Lecompton, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.0	275	4.6	6,710	7.2	15,200	9.8	24,300
2.2	625	4.8	7,300	7.4	15,900	10.0	25,000
2.4	1,000	5.0	7,900	7.6	16,600	10.5	27,500
2.6	1,425	5.2	8,510	7.8	17,300	11.0	30,000
2.8	1,885	5.4	9,130	8.0	18,000	11.5	32,750
3.0	2,375	5.6	9,770	8.2	18,700	12.0	35,500
3.2	2,890	5.8	10,430	8.4	19,400	12.5	38,625
3.4	3,415	6.0	11,110	8.6	20,100	13.0	41,750
3.6	3,940	6.2	11,790	8.8	20,800	13.5	45,375
3.8	4,465	6.4	12,470	9.0	21,500	14.0	49,000
4.0	5,000	6.6	13,150	9.2	22,200	15.0	58,000
4.2	5,550	6.8	13,830	9.4	22,900	16.0	67,000
4.4	6,120	7.0	14,510	9.6	23,600	17.0	76,000

Estimated monthly discharge of Kansas River at Lecompton, Kans.

[Drainage area, 58,550 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	1,000	445	767	47,161	0.01	0.01
February	625	275	492	27,324	.01	.01
March	3,675	100	2,460	151,259	.04	.05
April	3,415	2,250	2,653	157,864	.05	.06
May	23,075	2,125	8,435	518,648	.14	.16
June	28,500	11,110	17,131	1,019,365	.29	.32
July	81,400	11,450	38,291	2,354,422	.65	.75
August	40,812	6,415	11,941	734,223	.20	.23
September	53,050	5,270	14,990	891,977	.26	.29
October	42,112	9,130	17,734	1,090,421	.30	.35
November	13,320	9,450	10,830	644,430	.18	.20
December	15,900	9,130	11,785	724,631	.20	.23
The year	81,400	100	11,459	8,361,725	.20	2.66

BLUE RIVER NEAR MANHATTAN, KANS.

The gaging station, established April 12, 1895, is at the county bridge 4 miles north of Manhattan. The gage rod consists of three sections, the lower being an ash stick driven into the bottom of the river and bolted to an overhanging cottonwood tree, 30 feet east of the

bridge. The other two sections of the rod are bolted to the sou bridge pier. The bench mark is a cross cut in the capstone of t south bridge pier immediately above the upper gage, and is 32.1 feet above gage datum.

The observer is C. M. Matter.

Discharge measurements of Blue River near Manhattan, Kans.

Date.	Hydrographer.	Gage height.	Dischar
1902.		*Feet.*	*Second-f*
March 14	W. G. Russell	4.10	
April 29	do	3.80	
May 20	do	5.00	
June 10	do	18.05	17,
June 26	do	6.70	1,
July 9	do	25.15	31,
July 14 [a]	do	26.85	31,

[a] Backwater from Kansas River probably caused low discharge on July 14.

Daily gage height, in feet, of Blue River near Manhattan, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1	4.20	(a)	[a]4.80	4.00	3.80	5.50	22.00	11.50	24.50	10.10	6.50	
2	4.00	(a)	4.90	4.10	3.80	5.30	21.50	10.90	20.90	8.10	6.40	
3	3.80	[a]3.80	5.00	4.10	3.80	5.20	19.30	10.00	17.90	7.60	9.90	
4	3.80	(a)	4.70	4.10	4.80	5.10	18.70	9.40	13.10	13.10	8.80	
5	3.90	[a]4.10	.....	4.20	4.10	5.00	18.60	8.80	9.40	15.60	7.30	
6	4.00	(a)	.....	4.20	3.90	7.20	14.20	7.90	8.60	14.30	6.90	
7	4.00	(a)	4.80	4.20	3.90	6.80	9.70	7.80	8.20	12.30	6.50	
8	3.90	[a]4.20	4.60	4.20	3.90	13.00	19.40	7.60	7.90	11.30	6.40	
9	3.90	(a)	4.60	4.20	3.90	16.00	25.00	7.50	7.40	9.70	6.30	
10	3.80	(a)	4.50	4.10	3.90	18.50	29.00	7.30	7.10	9.00	6.20	
11	4.00	[a]4.20	4.40	4.00	4.00	18.00	31.50	7.00	7.10	8.40	6.20	
12	3.90	(a)	4.30	4.00	4.00	14.00	31.20	6.90	6.90	8.80	6.20	
13	3.90	(a)	4.30	4.00	3.80	12.10	30.00	6.90	6.60	19.30	6.10	
14	3.90	[a]4.30	4.10	4.00	4.80	11.60	28.50	6.80	6.50	16.20	6.70	
15	3.90	(a)	4.10	4.00	4.60	13.70	18.70	6.70	6.50	12.30	7.60	
16	3.90	[a]4.40	4.10	4.00	4.60	12.60	12.80	6.50	6.30	11.20	7.60	
17	3.90	(a)	4.00	4.00	5.30	10.50	11.20	6.60	6.30	9.20	7.00	
18	3.90	(a)	4.10	4.00	4.70	10.30	10.70	6.50	6.20	8.80	6.60	
19	4.00	[a]4.40	4.20	4.00	5.30	10.60	11.20	6.50	6.10	8.30	6.50	
20	4.00	(a)	4.20	4.00	5.20	13.50	14.80	7.90	6.10	8.00	6.40	
21	4.00	(a)	4.20	3.90	4.90	15.50	13.20	8.20	6.00	7.80	6.40	
22	4.00	[a]4.50	4.10	3.90	10.20	12.00	12.50	7.90	6.10	7.60	6.30	
23	4.00	(a)	4.20	3.90	10.10	9.00	13.60	8.10	6.50	7.40	6.20	
24	4.10	(a)	4.20	3.90	10.30	8.70	13.40	8.40	7.60	7.20	6.10	
25	4.00	[a]4.70	4.10	3.90	18.00	7.50	14.80	8.20	10.70	7.10	6.10	
26	[a]4.00	(a)	4.20	3.90	14.10	6.80	15.30	8.10	10.90	7.00	6.10	
27	[a]3.90	[a]5.00	4.10	3.90	8.80	6.40	11.30	10.40	10.60	6.90	6.20	
28	(a)	[a]4.80	4.00	3.80	7.80	13.50	11.50	11.20	9.10	6.80	6.20	
29	[a]3.90	.....	4.00	3.80	6.40	11.80	11.60	11.30	8.10	6.80	6.10	
30	(a)	.....	4.00	3.80	6.00	11.60	11.70	15.00	9.30	6.60	6.10	
31	[a]4.00	.....	4.00	.....	5.70	.....	11.80	23.30	.....	6.50	.....	

[a] Frozen.

Rating table for Blue River near Manhattan, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.0	140	6.8	2,006	10.6	5,468	15.0	11,760
3.2	204	7.0	2,150	10.8	5,684	15.5	12,710
3.4	268	7.2	2,306	11.0	5,900	16.0	13,670
3.6	336	7.4	2,462	11.2	6,124	16.5	14,630
3.8	408	7.6	2,624	11.4	6,348	17.0	15,590
4.0	480	7.8	2,792	11.6	6,576	17.5	16,550
4.2	560	8.0	2,960	11.8	6,808	18.0	17,510
4.4	640	8.2	3,136	12.0	7,040	18.5	18,470
4.6	726	8.4	3,312	12.2	7,280	19.0	19,430
4.8	818	8.6	3,492	12.4	7,520	19.5	20,390
5.0	910	8.8	3,676	12.6	7,764	20.0	21,350
5.2	1,014	9.0	3,860	12.8	8,012	21.0	23,270
5.4	1,118	9.2	4,052	13.0	8,260	22.0	25,190
5.6	1,228	9.4	4,244	13.2	8,560	23.0	27,110
5.8	1,344	9.6	4,440	13.4	8,860	24.0	29,030
6.0	1,460	9.8	4,640	13.6	9,186	25.0	30,950
6.2	1,592	10.0	4,840	13.8	9,538		
6.4	1,724	10.2	5,048	14.0	9,890		
6.6	1,862	10.4	5,256	14.5	10,820		

Estimated monthly discharge of Blue River near Manhattan, Kans.

[Drainage area, 9,490 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	560	408	461	28,346	0.05	0.06
February	910	408	619	34,378	.07	.07
March	910	480	618	37,983	.07	.08
April	560	408	483	28,740	.05	.06
May	17,510	408	2,157	132,629	.23	.27
June	17,510	910	6,298	374,757	.66	.74
July	43,430	4,540	16,866	1,037,050	1.78	2.05
August	27,686	1,790	4,329	266,180	.46	.53
September	29,990	1,460	5,011	298,175	.53	.59
October	20,006	1,790	5,071	311,804	.53	.61
November	4,740	1,526	1,945	115,735	.20	.22
December	3,136	1,066	1,897	116,642	.20	.23
The year	43,430	408	3,813	2,782,419	.40	5.51

REPUBLICAN RIVER AT JUNCTION, KANS.

The gaging station at this point, established by Arthur P. Da April 26, 1895, is located at the wagon bridge at the north en Washington street just above the mouth of the river. The gage sists of two oak timbers bolted to a post and to a cottonwood t One bench mark consists of a 60-penny spike driven into the bas the abutment of the bridge at an elevation of 10.67 feet on the the second bench mark is the top of a stone in the base of the br abutment 18 feet south of the gage and at an elevation of 14.51 above gage datum. The right bank is high, but the left is low and overflow at high water. The bed of the stream is sandy and liabl change.

On October 23, 1900, a new bench mark was established, at an el tion of 12.35 feet above the zero of the old gage. It is a spike dr in the west side of a cottonwood tree 18 inches in diameter and 10 west of the bridge. The spike is about 2 feet above the grou The observer is J. H. Rathert.

Discharge measurements of Republican River at Junction, Kans.

Date.	Hydrographer.	Gage height.	Disch
1902.		*Feet.*	*Second*
March 13	W. G. Russell	4.00	
April 29	do	3.65	
May 19	do	5.10	2
June 5	do	4.80	1
June 16	do	5.10	2
June 25	do	4.80	1
July 7	do	7.55	7
July 8	do	10.25	1
July 15	do	6.65	3
September 27	do	8.50	1

Daily gage height, in feet, of Republican River at Junction, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.80	3.90	4.60	4.35	3.60	5.50	9.67	5.75	7.30	5.00	3.50	3.45
2	3.80	3.90	4.20	4.30	3.55	5.30	8.50	5.00	5.60	4.65	3.50	3.40
3	3.85	3.90	4.20	4.10	3.55	5.10	8.20	5.35	5.00	4.60	3.95	3.40
4	3.85	3.90	4.30	4.00	4.63	6.10	9.30	4.80	4.20	6.60	3.95	3.40
5	3.80	3.90	4.40	4.00	4.00	4.80	7.80	4.55	3.85	5.35	3.60	3.35
6	3.80	3.90	4.50	3.90	3.80	5.30	7.25	4.25	3.45	5.30	3.50	3.10
7	3.75	3.90	4.60	3.90	3.75	5.90	7.10	4.20	3.40	5.15	3.45	3.10
8	3.75	3.90	4.50	3.80	3.70	7.50	10.60	4.10	3.30	5.10	3.40	3.00
9	3.75	3.90	4.30	3.85	3.65	6.85	10.40	3.85	3.25	4.60	3.45	3.00
0	3.80	3.90	4.20	3.80	3.65	6.40	11.20	6.10	3.20	4.20	3.45	3.20
1	3.90	3.90	4.00	3.80	3.55	5.85	12.30	3.80	3.20	4.00	3.45	3.20
2	3.90	3.90	4.00	3.85	3.55	5.10	12.70	3.60	3.10	4.90	3.45	3.20
3	3.80	3.90	4.00	3.80	3.95	7.40	10.10	3.50	2.90	4.90	3.40	3.20
4	3.80	3.90	3.90	3.75	4.95	5.45	7.60	3.40	2.90	6.70	3.50	3.18
5	3.85	3.90	3.90	3.70	4.70	6.20	6.60	4.50	2.90	4.90	3.65	3.08
6	3.90	3.90	3.85	3.72	4.00	5.20	6.20	3.35	2.85	4.80	3.70	3.12
7	3.90	3.90	3.85	3.72	4.40	4.80	5.75	3.25	2.65	4.40	3.60	3.25
8	3.90	3.90	3.80	3.70	4.20	5.50	5.40	3.10	2.80	4.20	3.60	3.30
9	3.90	3.90	3.80	3.70	4.50	5.40	5.00	3.50	2.75	4.00	3.50	3.30
0	3.90	3.90	3.75	3.60	5.40	5.60	4.80	3.60	2.75	3.85	3.50	3.35
1	4.00	3.90	3.70	3.60	6.10	6.20	4.70	7.60	2.70	3.90	3.50	3.65
2	4.00	3.90	3.90	3.70	6.40	5.30	5.30	4.70	2.70	3.85	3.45	3.38
3	4.10	3.90	3.90	3.65	6.55	5.00	4.75	3.90	3.35	3.80	3.40	3.35
4	4.00	3.90	3.85	3.60	6.60	4.90	4.40	3.90	3.65	3.75	3.50	3.30
5	3.90	4.00	3.80	3.60	6.65	4.80	4.20	3.80	5.10	3.65	3.50	3.28
6	3.90	4.00	3.90	3.65	7.60	4.60	4.20	3.50	8.20	3.60	3.40	3.28
7	3.90	4.10	3.90	3.65	6.70	4.40	4.00	5.85	8.50	3.55	3.40	3.30
8	3.90	4.55	3.85	3.65	5.60	5.23	4.20	5.10	5.90	3.55	3.45	3.65
9	3.90	.....	3.85	3.62	5.70	7.60	8.20	6.65	5.70	3.50	3.45	3.42
0	3.90	.....	3.90	3.65	5.60	7.80	8.40	6.95	5.50	3.50	3.40	3.85
1	3.90	.....	4.10	.....	5.90	.....	7.50	8.90	.....	3.45	.....	3.48

Rating table for Republican River at Junction, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.2	20	4.6	1,480	7.0	6,000	9.4	13,200
2.4	30	4.8	1,720	7.2	6,600	9.6	13,800
2.6	70	5.0	1,960	7.4	7,200	9.8	14,400
2.8	140	5.2	2,210	7.6	7,800	10.0	15,000
3.0	220	5.4	2,520	7.8	8,400	10.2	15,600
3.2	300	5.6	2,840	8.0	9,000	10.4	16,200
3.4	400	5.8	3,200	8.2	9,600	10.6	16,800
3.6	510	6.0	3,600	8.4	10,200	10.8	17,400
3.8	630	6.2	4,000	8.6	10,800	11.0	18,000
4.0	840	6.4	4,400	8.8	11,400	11.5	19,500
4.2	1,050	6.6	4,900	9.0	12,000	12.0	21,000
4.4	1,260	6.8	5,400	9.2	12,600	13.0	24,000

Estimated monthly discharge of Republican River at Junction, Kans.

[Drainage area 25,817 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
January	945	600	710	43,656	0.03	0.03
February	1,425	735	775	43,041	.03	.03
March	1,480	570	887	54,539	.03	.03
April	1,207	510	654	38,916	.03	.03
May	7,800	482	2,128	130,846	.08	.09
June	8,400	1,260	3,338	198,625	.13	.15
July	23,100	840	7,887	484,953	.30	.35
August	11,700	260	2,046	125,804	.08	.09
September	10,500	88	1,646	97,944	.06	.07
October	5,150	427	1,436	88,296	.06	.07
November	787	400	471	28,026	.02	.02
December	2,443	220	422	25,944	.02	.02
The year	23,100	88	1,867	1,360,590	.07	.98

REPUBLICAN RIVER AND THE MILL RACE NEAR SUPERIOR, NEBR.

This station was established June 20, 1896, about one mile west of Superior, Nebr. The old gage rod was first placed just above the highway bridge, which is itself 75 yards above the dam which diverts water into the mill race.

This gage consists of an oak piece 2 by 4 inches, 10 feet long. The face is inclined 30 degrees to the horizontal, and the footmarks are placed 2 feet apart to correspond to this inclination. The rod is fastened to cross-ties which are bedded in the bank of the river. The location is on the outside of an easy bend in the river. The bed of the river is of mud and sand. The top of the rim of the upstream cylinder of the north pier is 15.42 feet above the zero of the gage. Bench mark 2 is the standard 4-foot iron pipe of the United States Geological Survey. It is 83 feet north of the upstream cylinder of the north pier of the bridge and is 10 feet west of the line of the upstream truss of the bridge. It is 1 foot inside a wire fence. The top of the pipe is 4 inches above the ground and the elevation is 4.88 feet above gage datum.

In the spring of 1898 two other gages were established. The first gage was placed in the river a few feet upstream from the crest of the dam, the zero being at the same elevation as the crest. The second i

n the mill race, which is crossed by a wagon bridge about 50 yards below its head. Discharge measurements of the river are made from the highway bridge, thus determining at once the discharge through the mill race and from the dam. The discharge from the mill race is measured and is deducted from the total discharge of the river to give the amount passing over the dam. The bench mark for this river gage is bench mark No. 2 of the old gage described above. Its elevation is 4.92 feet above the datum of the gage at the dam. The gage of the mill race reads 2 feet higher than that of the river gage, so that its zero is 6.92 feet below the same bench mark.

It was found, however, that the discharge of the mill race was regulated more or less by the mill below, so that there was no relation whatever between the gage height and the discharge. To remedy this difficulty the observer records the depth of water in midstream at the wagon bridge and immediately thereafter notes number of seconds required for a float to pass over a 50-foot range in midstream. The ratios of the time to the depth was found to bear a constant relation to the discharge.

During 1899 Glenn E. Smith made an examination of a portion of the upper Republican River. On September 6, 1899, at Oxford, Nebr., the river channel was dry and was reported to have been in this condition for ten days. At Orleans, about 12 miles below, there was an estimated discharge of 0.3 second-foot—this small amount coming from Sappa River, which enters at this point.

Discharge measurements of Republican River near Superior, Nebr.[a]

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 16	Frank Dobson	0.75	625
April 5	J. C. Stevens	.70	638
May 24	Frank Dobson	1.30	1,499
July 8	J. C. Stevens	([b])	12,494
July 30	do	1.25	1,562
August 12	do	.73	553
September 19	do	.39	154

[a] These discharges include that flowing in the mill race.
[b] Water out of banks on both sides and over top of gage rod.

Discharge measurements of mill race near Superior, Nebr.[a]

Date.	Hydrographer	Discharge.	Date.	Hydrographer.	Dis-charg
1902.		*Sec.-feet.*	1902.		*Sec.-fe*
March 16	Frank Dobson	22	July 30	J. C. Stevens	1
April 5	J. C. Stevens	54	August 12	do	
May 24	Frank Dobson	35	September 19	do	

[a] Gage heights are not observed, but depth of water in midstream and the time required for a fl to pass over a 50-foot range in midstream, the ratios of which are used instead of gage heights.

Daily gage height, in feet, of Republican River near Superior, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	No
1902.									
1		0.80	0.56	1.10	1.98	1.42	0.70	1.00	
2		.80	.50	1.00	2.32	1.20	.68	.98	
3		.71	.70	1.05	2.05	1.05	.65	1.05	
4		.73	.46	1.32	1.30	1.18	.61	1.19	
5		.70	.49	.95	2.40	.95	.60	1.35	
6		.70	.53	1.95	(b)	.92	.58	1.00	
7		.62	.90	1.90	(b)	.90	.52	.98	
8	(a)	.56	1.02	1.92	(b)	.82	.53	.90	
9	0.90	.55	1.15	1.48	(b)	.80	.45	.89	
10	.85	.58	.85	1.30	3.50	.70	.42	.82	
11	.80	.68	.75	1.42	2.55	.81	.48	.88	
12	.80	.78	.69	1.00	1.88	.70	.40	1.05	
13	.80	.68	.86	.95	1.92	.62	.32	1.45	
14	.83	.60	.80	.88	1.72	.80	.31	1.00	
15	.75	.60	.78	1.05	1.42	.78	.40	.85	
16	.75	.62	.70	.82	1.30	.65	.41	.82	
17	.70	.68	.70	.70	1.15	.60	.32	.99	
18	.85	.65	.75	.75	1.68	.55	.48	.90	
19	.80	.52	1.85	1.38	1.80	.52	.34	.91	
20	.64	.70	1.69	1.20	1.10	.51	.35	.83	
21	.60	.65	1.53	1.20	1.05	.50	.40	.78	
22	.75	.63	1.42	1.08	1.00	.52	1.85	.70	
23	.78	.67	1.20	.95	.92	.68	3.60	.71	
24	.75	.65	1.30	.90	1.02	.50	2.32	.72	
25	.78	.62	1.56	.82	1.08	.50	1.86	.70	
26	.80	.58	1.95	.76	[illegible]	.50	1.78	.73	
27	.81	.60	1.95	.68	3.25	.60	1.35	.75	
28	.97	.56	1.65	.65	3.00	.58	1.10	.75	
29	.52	.56	1.75	.78	1.60	.59	1.05	.72	
30	.83	.52	1.25	1.10	1.20	.67	1.02	.71	[a]
31	.81		1.20		1.70	.62		.72	

[a] Observations discontinued from Jan. 1 to Mar. 9 and during December on account of ice.
[b] Flood; water over top of gage.

Rating table for Republican River near Superior, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.1	45	1.0	850	1.9	2,780	2.8	6,155
.2	95	1.1	1,010	2.0	3,075	2.9	6,630
.3	150	1.2	1,190	2.1	3,390	3.0	7,125
.4	215	1.3	1,390	2.2	3,725	3.1	7,650
.5	285	1.4	1,610	2.3	4,080	3.2	8,195
.6	360	1.5	1,840	2.4	4,455	3.3	8,760
.7	460	1.6	2,085	2.5	4,850	3.4	9,345
.8	570	1.7	2,340	2.6	5,265	3.5	9,950
.9	690	1.8	2,505	2.7	5,700	3.6	10,575

[a] This table was applied indirectly according to the method outlined on page 323, Nineteenth Annual Report United States Geological Survey, Part IV, and gives the discharge over the dam, exclusive of that flowing in the mill race.

Estimated monthly discharge of Republican River near Superior, Nebr.

[Drainage area, 22,347 square miles.]

Month.	Discharge in second-feet.			Run-off.		
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
March 9 to 31	.....	.....	675	29,453	0.03	0.02
April	740	390	555	33,020	.02	.02
May	2,810	335	1,269	78,020	.06	.07
June	3,235	320	1,372	81,640	.06	.07
July	12,490	970	[a] 3,080	[a] 189,360	[a] .14	[a] .16
August	1,920	330	674	41,440	.03	.03
September	10,875	155	1,175	69,910	.05	.06
October	1,995	520	937	57,610	.04	.05
November	970	460	622	37,010	.03	.03

[a] Exclusive of four days' flood discharge.

SOLOMON RIVER AT NILES, KANS.

The station at Niles was established May 5, 1897, and is located at a bridge one-half mile west of the town and 7 miles above the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. The bench mark is the uppermost of three nails driven into a cottonwood tree 18 inches in diameter, on the north side of the river and 25 feet east of the bridge, at an elevation of 24.96 feet above gage

Discharge measurements of Kansas River at Lecompton, Kans.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 28	W. G. Russell	3.00	1,340
May 28	do	7.00	14,314
June 9	do	8.25	17,182
June 21	do	6.50	13,147
July 12	do	16.35	72,17[illegible]
July 30	do	6.15	12,87[illegible]
August 27	do	7.70	17,72[illegible]

Daily gage height, in feet, of Kansas River at Lecompton, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De[illegible]
1902.												
1	2.10	2.20	2.00	3.40	2.90	7.25	10.95	8.00	14.45	7.60	5.60	[illegible]
2	2.10	2.20	2.00	3.40	2.90	7.50	11.30	7.55	12.85	7.50	5.60	[illegible]
3	2.10	2.20	2.00	3.35	2.90	7.00	11.75	7.10	11.35	9.35	5.60	[illegible]
4	2.10	2.20	1.90	3.30	2.90	6.60	11.95	6.55	9.90	11.20	5.60	[illegible]
5	2.10	2.20	1.90	3.20	2.90	7.20	12.20	5.50	8.95	13.05	5.60	5
6	2.10	2.20	1.80	3.20	3.05	7.70	12.50	5.30	8.50	12.40	5.60	5
7	2.20	2.20	2.20	3.20	3.35	9.00	12.85	4.90	7.90	10.20	5.60	5
8	2.30	2.20	2.65	3.20	3.65	8.50	13.20	4.70	7.45	9.90	5.60	5
9	2.40	2.20	2.85	3.20	3.80	7.95	13.80	4.60	6.90	9.55	5.60	5
10	2.40	2.20	3.15	3.10	3.75	9.50	14.60	4.90	6.60	8.70	5.60	5
11	2.40	2.20	3.40	3.10	3.70	9.60	15.30	5.40	6.10	7.65	5.50	5
12	2.40	2.20	3.35	3.10	3.75	9.20	16.30	4.95	5.20	7.65	5.55	5.
13	2.40	2.20	3.20	3.10	3.95	8.50	16.85	4.90	4.70	8.20	5.70	5.
14	2.40	2.10	3.00	3.10	4.25	7.80	17.40	4.85	4.30	9.75	5.90	5.
15	2.35	2.10	3.00	3.10	4.50	7.50	17.60	4.80	4.30	9.30	6.00	5.
16	2.30	2.10	3.50	3.10	4.90	7.25	16.65	4.80	4.30	8.55	6.00	5.
17	2.30	2.10	3.50	3.10	4.90	6.90	15.55	4.70	4.25	7.90	6.10	5.
18	2.30	2.10	3.40	3.05	4.70	6.70	13.50	4.65	4.20	7.35	6.40	5.
19	2.30	2.10	3.40	3.00	4.95	6.50	11.50	4.60	4.15	6.90	6.65	5.
20	2.30	2.00	3.40	3.00	5.40	6.45	12.80	4.50	4.10	6.45	6.50	6.
21	2.30	2.00	3.30	3.00	5.70	6.65	10.60	5.15	4.10	6.05	6.40	7.
22	2.30	2.00	3.30	3.00	6.20	8.80	8.60	5.55	4.30	6.00	6.20	7.
23	2.30	2.10	3.50	3.00	6.70	8.45	7.00	6.75	5.80	5.90	6.20	7.
24	2.30	2.10	3.50	3.00	10	7.70	7.30	6.60	6.20	5.70	6.20	7.
25	2.30	2.10	3.40	3.00	75	7.15	7.05	6.50	6.40	5.60	6.15	7.
26	2.30	2.00	3.40	3.00	8.40	6.70	7.00	6.85	6.65	5.60	6.10	7.
27	2.30	2.00	3.30	3.00	9.45	6.35	7.00	7.75	6.90	5.60	6.05	7.
28	2.30	2.00	3.30	3.00	9.25	6.00	6.80	8.00	8.30	5.50	6.00	7.
29	2.30	.....	3.30	5.00	7 60	9.00	6.35	8.20	8.80	5.40	6.00	7
30	2.30	.....	3.30	2.95	5.65	10.70	6.10	8.85	7.90	5.40	5.80	7
31	2.20	.....	3.30		5.55	.....	7.15	12.85	.....	5.40	.....	6

Rating table for Solomon River at Niles, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.0	22	7.4	470	10.8	1,285	14.5	2,375
4.2	38	7.6	512	11.0	1,337	15.0	2,550
4.4	54	7.8	556	11.2	1,389	16.0	2,900
4.6	70	8.0	600	11.4	1,441	17.0	3,250
4.8	86	8.2	646	11.6	1,493	18.0	3,600
5.0	102	8.4	692	11.8	1,547	19.0	3,950
5.2	122	8.6	738	12.0	1,604	20.0	4,300
5.4	142	8.8	784	12.2	1,663	21.0	4,650
5.6	162	9.0	830	12.4	1,722	22.0	5,000
5.8	192	9.2	880	12.6	1,782	23.0	5,350
6.0	222	9.4	930	12.8	1,841	24.0	5,700
6.2	252	9.6	980	13.0	1,900	25.0	6,050
6.4	282	9.8	1,030	13.2	1,960	26.0	6,400
6.6	316	10.0	1,080	13.4	2,020	27.0	6,800
6.8	352	10.2	1,130	13.6	2,080	28.0	7,220
7.0	390	10.4	1,181	13.8	2,140	29.0	7,730
7.2	430	10.6	1,233	14.0	2,200	30.0	8,300

Estimated monthly discharge of Solomon River at Niles, Kans.

[Drainage area, 6,815 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	152	94	106	6,517	0.02	0.02
ebruary	142	102	119	6,608	.02	.02
larch	207	38	101	6,210	.02	.02
pril	152	54	89	5,296	.01	.01
lay	1,415	38	285	17,524	.04	.05
une	6,155	316	1,392	82,830	.20	.22
uly	7,040	252	2,492	153,227	.37	.43
ugust	2,375	299	847	52,080	.12	.14
eptember	7,040	132	1,392	82,830	.20	22
ctober	7,780	761	2,263	139,145	.33	38
ovember	855	470	601	35,764	.09	.10
ecember	490	316	402	24,718	.06	.07
The year	*7,780*	*38*	841	612,749	.12	1.68

SALINE RIVER NEAR SALINA, KANS.

The station, established May 4, 1897, is located at a bridge 4.5 miles northeast of Salina, near the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. Bench mark No. 1 is a nail in an elm tree 2 feet in diameter on the north side of the river and 6 feet west of the bridge. Its elevation is 22.90 feet above gage datum. Bench mark No. 2 is six nails driven into a 16-inch box-elder tree on the north side of the river and 35 east of the bridge. Its elevation is 22.90 feet above gage datum. The channel is straight for a short distance above and below the station. Both banks are high and not liable to overflow. The bed of the stream is sand and mud. The observer is Charley Tressin.

Discharge measurements of Saline River near Salina, Kans.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 6	W. G. Russell	4.00	22
April 30	do	3.30	23
May 11	do	3.20	24
June 2	do	4.70	116
June 11	do	6.80	326
July 2	do	17.40	2,017
July 23	do	4.80	131
September 30	do	24.50	3,822
October 2	do	21.10	2,664
November 29	do	6.10	231

Daily gage height, in feet, of Saline River near Salina, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.70	(a)	4.10	3.60	3.40	5.70	15.80	6.10	9.00	24.50	7.20	6.10
2	3.70	a 4.10	4.30	3.50	3.40	4.60	18.20	5.50	13.50	20.90	7.20	6.10
3	3.80	(a)	4.30	3.60	3.30	4.20	20.20	5.20	12.00	10.80	7.70	6.10
4	3.90	a 4.00	3.80	3.50	3.20	4.30	20.30	5.00	8.60	15.30	7.60	6.00
5	4.20	(a)	3.80	3.50	3.40	9.10	10.50	5.00	7.50	15.70	7.20	6.10
6	4.00	a 4.00	3.60	3.40	3.40	12.00	8.90	4.80	6.60	15.00	7.00	6.0
7	4.00	(a)	3.70	3.60	3.3[illegible]	15.80	7.90	4.70	6.20	16.10	6.90	5.7
8	4.10	a 4.10	3.90	3.40	3.3[illegible]	16.90	11.50	4.60	5.90	16.90	6.70	5.5
9	4.10	a 4.10	3.90	3.40	3.40	13.90	9.50	5.70	5.70	15.00	6.80	5.[illegible]
10	4.20	(a)	3.70	3.50	3.3[illegible]	8.40	16.10	5.20	5.50	11.60	6.70	5.7
11	4.00	a 4.20	3.60	3.40	3.20	6.80	10.80	7.20	5.30	10.70	6.70	5.5
12	4.00	(a)	3.90	3.40	3.[illegible]	8.20	7.40	9.50	5.20	10.00	6.60	5.2
13	4.10	a 4.10	3.60	3.50	3.30	7.30	6.00	12.00	5.00	9.60	6.70	5.9
14	4.20	(a)	3.60	3.50	[illegible]	7.20	6.60	7.40	5.00	10.70	6.70	6.3

a Frozen.

Daily gage height, in feet, of Saline River near Salina, Kans.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	4.00	a 4.10	3.60	3.40	3.10	12.10	6.00	6.20	4.90	15.20	6.60	6.25
.....	4.20	a 4.20	3.60	3.40	3.20	12.50	5.70	5.50	4.90	17.10	6.60	6.20
.....	4.20	(a)	3.70	3.50	3.20	13.50	5.40	5.00	4.90	16.00	6.60	6.30
.....	4.20	a 4.20	3.60	3.40	3.10	14.40	5.30	4.70	4.80	10.80	6.40	6.20
.....	4.30	(a)	3.40	3.40	3.10	11.00	5.10	5.20	4.80	9.60	6.40	5.90
.....	4.50	(a)	3.60	3.30	3.20	8.40	5.10	5.10	4.80	9.10	6.40	5.60
.....	4.00	a 3.90	3.50	3.40	3.50	14.90	4.80	5.30	4.70	8.70	6.30	5.80
.....	4.00	a 3.60	3.40	3.50	4.00	14.50	4.90	6.20	5.00	8.40	6.30	5.90
.....	4.00	3.80	3.50	3.40	4.00	12.70	4.80	10.00	12.00	8.20	6.30	6.05
.....	4.00	3.60	3.50	3.30	3.50	7.90	4.80	14.40	17.80	8.10	6.30	5.95
.....	4.10	3.60	3.60	3.30	7.20	7.50	4.70	14.00	17.50	7.90	6.20	5.90
.....	a 4.20	3.80	3.60	3.50	7.50	6.80	4.90	15.40	18.00	7.80	6.30	6.10
.....	(a)	3.90	3.60	3.40	6.70	6.30	4.80	16.70	19.60	7.70	6.20	6.35
.....	a 4.30	3.80	3.60	3.20	7.00	6.30	4.90	17.00	21.40	7.50	6.20	5.85
.....	(a)	.....	3.60	3.30	9.70	13.10	4.70	10.00	23.40	7.40	6.10	5.70
.....	a 4.00	.....	3.60	3.10	7.20	13.70	7.50	7.50	24.50	7.30	6.10	5.60
.....	a 4.10	.....	3.60	.....	5.80	.....	6.40	6.90	.....	7.20	.....	5.65

a Frozen.

Rating table for Saline River near Salina, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.2	28	6.8	320	10.4	796	14.0	1,370
3.4	34	7.0	340	10.6	824	14.5	1,460
3.6	41	7.2	364	10.8	852	15.0	1,550
3.8	50	7.4	388	11.0	880	15.5	1,640
4.0	60	7.6	412	11.2	910	16.0	1,730
4.2	70	7.8	436	11.4	940	16.5	1,820
4.4	80	8.0	460	11.6	970	17.0	1,910
4.6	100	8.2	488	11.8	1,000	17.5	2,000
4.8	120	8.4	516	12.0	1,030	18.0	2,090
5.0	140	8.6	544	12.2	1,064	18.5	2,180
5.2	160	8.8	572	12.4	1,098	19.0	2,270
5.4	180	9.0	600	12.6	1,132	19.5	2,360
5.6	200	9.2	628	12.8	1,166	20.0	2,450
5.8	220	9.4	656	13.0	1,200	20.5	2,545
6.0	240	9.6	684	13.2	1,234	21.0	2,640
6.2	260	9.8	712	13.4	1,268	22.0	2,860
6.4	280	10.0	740	13.6	1,302	23.0	3,170
6.6	300	10.2	768	13.8	1,336	24.0	3,620

REPUBLICAN RIVER AT JUNCTION, KANS.

The gaging station at this point, established by Arthur P. I April 26, 1895, is located at the wagon bridge at the north e Washington street just above the mouth of the river. The gag sists of two oak timbers bolted to a post and to a cottonwood One bench mark consists of a 60-penny spike driven into the b the abutment of the bridge at an elevation of 10.67 feet on the the second bench mark is the top of a stone in the base of the b abutment 18 feet south of the gage and at an elevation of 14.5 above gage datum. The right bank is high, but the left is low an overflow at high water. The bed of the stream is sandy and lia change.

On October 23, 1900, a new bench mark was established, at an tion of 12.35 feet above the zero of the old gage. It is a spike d in the west side of a cottonwood tree 18 inches in diameter and 1 west of the bridge. The spike is about 2 feet above the gr The observer is J. H. Rathert.

Discharge measurements of Republican River at Junction, Kans.

Date.	Hydrographer.	Gage height.	Dis
1902.		*Feet.*	*Seco*
March 13	W. G. Russell	4.00	
April 29	do	3.65	
May 19	do	5.10	
June 5	do	4.80	
June 16	do	5.10	
June 25	do	4.80	
July 7	do	7.55	
July 8	do	10.25	
July 15	do	6.65	
September 27	do	8.50	

Daily gage height, in feet, of Smoky Hill River at Ellsworth, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	[a] 1.20	[a] 0.80	1.50	0.95	0.75	1.30	5.20	2.90	3.00	3.60	1.80	1.25
.....	[a] 1.20	[a] .80	1.40	.95	.75	1.20	4.60	2.75	2.80	3.40	1.85	1.25
.....	[a] 1.20	[a] .80	1.30	.90	.75	1.20	4.30	2.60	2.70	3.60	1.85	1.20
.....	[a] 1.20	[a] .80	1.20	.90	.75	2.20	3.90	2.50	2.60	4.10	1.80	1.20
.....	[a] .90	[a] .80	1.10	.90	.75	1.70	3.40	2.30	2.40	4.20	1.80	1.20
.....	[a] .90	[a] .80	1.10	.90	.75	1.50	3.00	2.10	2.30	4.00	1.75	1.20
.....	[a] .90	[a] .80	1.00	.90	.70	1.30	2.80	2.00	2.20	3.80	1.70	1.20
.....	[a] .90	[a] .80	1.00	.85	.70	1.25	3.80	2.25	2.00	3.50	1.60	1.15
.....	[a] .90	[a] .85	1.00	.85	.70	1.20	3.40	2.20	1.90	3.30	1.60	1.15
.....	[a] .90	[a] .85	.95	.85	.70	1.20	3.00	1.95	1.85	3.10	1.55	1.15
.....	[a] .90	[a] .85	.95	.85	.70	1.15	6.70	1.80	1.80	2.90	1.50	1.15
.....	[a] .90	[a] .90	.95	.80	.70	1.10	5.60	1.80	1.70	2.70	1.60	1.10
.....	[a] .90	[a] .90	.90	.80	.70	3.00	5.00	1.75	1.70	2.50	1.65	1.10
.....	[a] .90	[a] .90	.90	.80	.85	2.00	4.50	2.20	1.65	2.80	1.70	1.10
.....	[a] .85	[a] .90	.90	.80	.80	1.70	3.50	2.00	1.60	3.00	1.65	1.20
.....	[a] .85	[a] .95	90	.80	.80	2.50	2.70	1.80	1.60	2.60	1.65	1.20
.....	[a] .85	[a] .95	85	.80	.75	2.30	2.50	1.60	1.55	2.60	1.65	1.20
.....	[a] .85	[a] 1.10	85	.80	.80	2.10	2.20	1.40	1.50	2.50	1.60	1.20
.....	.85	[a] 1.20	85	.80	.85	2.10	2.00	1.30	1.50	2.35	1.60	1.30
.....	.85	[a] 1.20	85	75	.85	8.75	1.90	1.25	1.50	2.30	1.60	1.40
.....	.85	[a] 1.30	90	75	1.60	5.50	1.80	3.80	1.50	2.20	1.55	1.40
.....	.80	[a] 1.50	90	85	2.20	4.90	1.80	6.50	1.65	2.20	1.55	1.30
.....	.80	1.10	90	85	2.20	6.00	1.70	8.30	3.00	2.15	1.50	([a])
.....	.80	1.20	95	85	2.00	4.50	1.65	12.00	12.60	2.10	1.50	([a])
.....	[a] .80	1.20	95	80	80	3.80	3.00	6.50	9.00	2.00	1.45	1.40
.....	[a] .80	1.30	2.15	80	3.05	3.50	2.60	5.00	7.80	2.00	1.40	([a])
.....	[a] .80	1.50	1.00	80	70	3.20	2.40	4.20	6.20	2.00	1.35	([a])
.....	[a] .80	1.50	1.00	80	1.50	3.00	2.20	3.50	5.20	1.95	1.30	([a])
.....	[a] .80	.....	95	80	1.50	5.40	2.00	3.30	4.60	1.90	1.25	([a])
.....	[a] .80	.....	95	80	1.50	5.00	3.40	3.10	3.90	1.85	1.25	([a])
.....	[a] .80	.....	95		1.45	.....	3.20	3.80	.....	1.85	.....	([a])

[a] River frozen.

Rating table for Smoky Hill River at Ellsworth, Kans., for 1902.

ge ht.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
et.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
.6	9	2.6	485	4.6	1,670	6.6	3,190
.8	17	2.8	575	4.8	1,810	6.8	3,345
.0	25	3.0	675	5.0	1,950	7.0	3,500
.2	55	3.2	780	5.2	2,105	8.0	4,275
.4	85	3.4	900	5.4	2,260	9.0	5,050
.6	125	3.6	1,020	5.6	2,415	10.0	5,825
.8	175	3.8	1,140	5.8	2,570	11.0	6,600
.0	235	4.0	1,260	6.0	2,725	12.0	7,375
.2	310	4.2	1,390	6.2	2,880		
.4	395	4.4	1,530	6.4	3,035		

Estimated monthly discharge of Republican River at Junction, Kans.

[Drainage area 25,837 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
January	945	600	710	43,656	0.03	0.03
February	1,425	735	775	43,041	.03	.03
March	1,480	570	887	54,539	.03	.03
April	1,207	510	654	38,916	.03	.03
May	7,800	482	2,128	130,846	.08	.09
June	8,400	1,260	3,338	198,625	.13	.15
July	22,100	840	7,887	484,953	.30	.35
August	11,700	260	2,046	125,804	.08	.09
September	10,500	88	1,646	97,944	.06	.07
October	5,150	427	1,436	88,296	.06	.07
November	787	400	471	28,026	.02	.02
December	2,443	220	422	25,944	.02	.02
The year	23,100	88	1,867	1,360,590	.07	.98

REPUBLICAN RIVER AND THE MILL RACE NEAR SUPERIOR, NEBR.

This station was established June 20, 1896, about one mile west of Superior, Nebr. The old gage rod was first placed just above the highway bridge, which is itself 75 yards above the dam which diverts water into the mill race.

This gage consists of an oak piece 2 by 4 inches, 10 feet long. The face is inclined 30 degrees to the horizontal, and the footmarks are placed 2 feet apart to correspond to this inclination. The rod is fastened to cross-ties which are bedded in the bank of the river. The location is on the outside of an easy bend in the river. The bed of the river is of mud and sand. The top of the rim of the upstream cylinder of the north pier is 15.42 feet above the zero of the gage. Bench mark 2 is the standard 4-foot iron pipe of the United States Geological Survey. It is 83 feet north of the upstream cylinder of the north pier of the bridge and is 10 feet west of the line of the upstream truss of the bridge. It is 1 foot inside a wire fence. The top of the pipe is 4 inches above the ground and the elevation is 4.88 feet above gage datum.

In the spring of 1898 two other gages were established. The first gage was placed in the river a few feet upstream from the crest of the dam, the zero being at the same elevation as the crest. The second is

in the mill race, which is crossed by a wagon bridge about 50 yards below its head. Discharge measurements of the river are made from the highway bridge, thus determining at once the discharge through the mill race and from the dam. The discharge from the mill race is measured and is deducted from the total discharge of the river to give the amount passing over the dam. The bench mark for this river gage is bench mark No. 2 of the old gage described above. Its elevation is 4.92 feet above the datum of the gage at the dam. The gage of the mill race reads 2 feet higher than that of the river gage, so that its zero is 6.92 feet below the same bench mark.

It was found, however, that the discharge of the mill race was regulated more or less by the mill below, so that there was no relation whatever between the gage height and the discharge. To remedy this difficulty the observer records the depth of water in midstream at the wagon bridge and immediately thereafter notes number of seconds required for a float to pass over a 50-foot range in midstream. The ratios of the time to the depth was found to bear a constant relation to the discharge.

During 1899 Glenn E. Smith made an examination of a portion of the upper Republican River. On September 6, 1899, at Oxford, Nebr., the river channel was dry and was reported to have been in this condition for ten days. At Orleans, about 12 miles below, there was an estimated discharge of 0.3 second-foot—this small amount coming from Sappa River, which enters at this point.

Discharge measurements of Republican River near Superior, Nebr.[a]

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 16	Frank Dobson	0.75	625
April 5	J. C. Stevens	.70	638
May 24	Frank Dobson	1.30	1,499
July 8	J. C. Stevens	([b])	12,494
July 30	do	1.25	1,562
August 12	do	.73	553
September 19	do	.39	154

[a] These discharges include that flowing in the mill race.
[b] Water out of banks on both sides and over top of gage rod.

Discharge measurements of mill race near Superior, Nebr.[a]

Date.	Hydrographer	Discharge.	Date.	Hydrographer.	Dis chan
1902.		*Sec.-feet.*	1902.		*Sec.-f*
March 16	Frank Dobson	22	July 30	J. C. Stevens	
April 5	J. C. Stevens	54	August 12	do	
May 24	Frank Dobson	35	September 19	do	

[a] Gage heights are not observed, but depth of water in midstream and the time required for a t to pass over a 50-foot range in midstream, the ratios of which are used instead of gage heights.

Daily gage height, in feet, of Republican River near Superior, Nebr.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	N
1902.									
1		0.80	0.56	1.10	1.98	1.42	0.70	1.00	
2		.80	.50	1.00	2.32	1.20	.68	.98	
3		.71	.70	1.05	2.05	1.65	.65	1.05	
4		.73	.46	1.32	1.30	1.18	.61	1.19	
5		.70	.49	.95	2.40	.95	.60	1.35	
6		.70	.53	1.95	(b)	.92	.58	1.00	
7		.62	.90	1.90	(b)	.90	.52	.98	
8	(a)	.56	1.02	1.92	(b)	.82	.53	.90	
9	0.90	.55	1.15	1.48	(b)	.80	.45	.89	
10	.85	.58	.85	1.30	3.50	.70	.42	.82	
11	.80	.68	.75	1.42	2.55	.81	.48	.88	
12	.80	.78	.69	1.00	1.88	.70	.40	1.05	
13	.80	.68	.86	.95	1.92	.62	.32	1.45	
14	.83	.60	.80	.88	1.72	.80	.31	1.00	
15	.75	.60	.78	1.05	1.42	.78	.40	.85	
16	.75	.62	.70	.82	1.30	.65	.41	.82	
17	.70	.68	.70	.70	1.15	.60	.32	.99	
18	.85	.65	.75	[illegible]	1.68	[illegible]	.48	.90	
19	.80	.62	1.85	1.38	1.80	.52	.34	.91	
20	.64	.70	1.69	1.20	1.10	.51	.35	.83	
21	.60	.65	1.53	1.20	1.05	.50	.40	.78	
22	.75	.63	1.42	1.08	1.00	.52	1.85	.70	
23	.78	.67	1.20	.95	.92	.68	3.60	.71	
24	.75	.65	1.30	.90	1.02	.50	2.32	.72	
25	[illegible]	.62	1.56	.82	1.08	.50	1.86	.70	
26	.80	.58	1.95	.76	[illegible]	.50	1.78	.73	
27	.81	.61	1.95	.68	3.25	.60	1.35	.75	
28	.97	.56	1.65	.65	3.00	.58	1.10	.75	
29	.52	.56	1.75	.78	1.60	.59	1.05	.72	
30	.83	.52	1.25	1.10	1.20	.67	1.02	.71	[illegible]
31	.81	.....	1.20	.....	1.70	.62	.....	.72	.....

[a] Observations discontinued from Jan. 1 to Mar. 9 and during December on account of ice.
[b] Flood; water over top of gage.

Rating table for Republican River near Superior, Nebr., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.1	45	1.0	850	1.9	2,780	2.8	6,155
.2	95	1.1	1,010	2.0	3,075	2.9	6,630
.3	150	1.2	1,190	2.1	3,390	3.0	7,125
.4	215	1.3	1,390	2.2	3,725	3.1	7,650
.5	285	1.4	1,610	2.3	4,080	3.2	8,195
.6	360	1.5	1,840	2.4	4,455	3.3	8,760
.7	460	1.6	2,085	2.5	4,850	3.4	9,345
.8	570	1.7	2,340	2.6	5,265	3.5	9,950
.9	690	1.8	2,505	2.7	5,700	3.6	10,575

[a] This table was applied indirectly according to the method outlined on page 323, Nineteenth Annual Report United States Geological Survey, Part IV, and gives the discharge over the dam, exclusive of that flowing in the mill race.

Estimated monthly discharge of Republican River near Superior, Nebr.

[Drainage area, 22,347 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
March 9 to 31			675	29,453	0.03	0.02
April	740	390	555	33,020	.02	.02
May	2,810	335	1,269	78,020	.06	.07
June	3,235	320	1,372	81,640	.06	.07
July	12,490	970	[a] 3,080	[a] 189,360	[a] .14	[a] .16
August	1,920	330	674	41,440	.03	.03
September	10,875	155	1,175	69,910	.05	.06
October	1,995	520	937	57,610	.04	.05
November	970	460	622	37,010	.03	.03

[a] Exclusive of four days' flood discharge.

SOLOMON RIVER AT NILES, KANS.

The station at Niles was established May 5, 1897, and is located at a bridge one-half mile west of the town and 7 miles above the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. The bench mark is the uppermost of three nails driven into a cottonwood tree 13 inches in diameter, on the north side of the river and 25 feet east of the bridge, at an elevation of 24.96 feet above gage

datum. The channel is straight for about 100 feet above and bel the section. The current is sluggish; the right bank is high, and t left bank overflows only at very high stages. The bed of the stre is muddy.

The observer is J. J. Little.

Discharge measurements of Solomon River at Niles, Kans.

Date.	Hydrographer.	Gage height.	Dischar
1902.		*Feet.*	*Second-f*
April 30	W. G. Russell	4.50	
June 5	do	7.20	
June 26	do	7.80	
July 3	do	27.30	6,
October 1	do	29.10	8,

Daily gage height, in feet, of Solomon River at Niles, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1		(a)	(a)	4.60	4.60	9.10	26.10	14.50	8.40	29.10	8.70	
2		(a)	5.10	5.50	4.80	7.70	27.60	10.00	9.00	28.50	8.60	
3		a 5.00	5.00	5.30	4.70	6.60	27.30	10.00	9.70	14.70	8.80	
4	a 4.90	(a)	4.20	5.20	4.70	10.70	25.80	7.90	9.10	13.50	9.10	
5	(a)	a 5.30	4.30	5.10	4.60	7.60	21.70	7.70	7.50	13.90	8.60	
6	a 5.00	(a)	4.20	4.90	4.50	7.10	17.60	7.30	6.80	16.90	8.40	
7	(a)	(a)	5.70	4.80	4.60	9.80	13.40	7.00	6.40	17.30	8.30	
8	(a)	a 5.10	5.90	4.70	4.50	16.00	14.30	6.70	6.80	18.10	8.20	
9	(a)	(a)	5.70	4.60	4.50	14.50	17.10	6.70	6.80	16.00	8.20	
10	a 5.00	a 5.00	5.30	4.70	4.50	11.00	21.30	14.50	6.20	14.20	8.10	
11	(a)	(a)	5.30	4.90	4.60	10.40	22.10	14.00	5.80	12.30	8.10	
12	(a)	a 5.10	5.20	4.90	4.70	9.40	21.40	11.70	5.50	11.30	8.10	
13	a 4.90	(a)	5.20	4.80	4.80	8.20	20.30	9.50	5.50	14.30	8.10	
14	(a)	(a)	5.00	4.70	4.60	12.40	10.80	10.30	5.60	17.30	8.10	
15	a 5.00	a 5.20	4.90	4.90	4.60	7.80	9.20	10.70	5.60	16.80	8.10	
16	(a)	(a)	4.80	4.90	4.70	7.40	8.80	8.70	5.50	16.40	8.10	
17	a 4.90	(a)	4.80	4.70	4.60	8.80	8.00	7.70	5.60	14.40	7.80	
18	(a)	a 5.40	5.00	4.80	4.60	11.00	7.50	7.30	5.60	12.20	7.80	
19	a 5.20	(a)	4.70	4.90	4.20	12.40	7.30	7.00	5.40	14.40	7.80	
20	(a)	a 5.00	4.70	4.90	4.70	8.70	7.00	6.50	5.30	10.50	7.80	
21	(a)	(a)	4.70	4.60	4.60	12.50	6.80	7.70	5.30	10.30	7.70	
22	a 5.50	a 5.10	4.80	4.70	5.60	14.60	6.90	8.60	5.40	10.00	7.70	
23	(a)	(a)	5.00	4.80	5.80	12.10	6.70	8.00	5.30	9.80	7.60	
24	a 5.00	a 5.30	4.90	4.70	7.80	11.30	6.30	7.70	11.30	9.60	7.50	
25	(a)	(a)	4.90	4.80	7.60	9.50	6.60	8.60	18.20	9.60	7.50	
26	a 5.20	a 5.40	5.00	4.80	7.10	8.40	6.50	7.90	22.00	9.30	7.50	
27	(a)	(a)	4.90	4.80	11.30	7.10	6.30	8.10	22.70	9.30	7.40	
28	a 5.00	a 5.20	4.80	4.80	11.00	7.00	6.20	10.10	24.00	9.30	7.40	
29	(a)	.....	5.00	4.40	9.10	20.00	6.60	8.40	25.60	9.10	7.40	
30	(a)	.....	4.70	4.60	10.60	25.30	17.90	7.20	27.60	8.80	7.40	
31	a 5.00	.....	4.80	.....	8.40	.....	20.20	8.20	.....	8.70	.....	

a Frozen.

Rating table for Solomon River at Niles, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.0	22	7.4	470	10.8	1,285	14.5	2,375
4.2	38	7.6	512	11.0	1,337	15.0	2,550
4.4	54	7.8	556	11.2	1,389	16.0	2,900
4.6	70	8.0	600	11.4	1,441	17.0	3,250
4.8	86	8.2	646	11.6	1,493	18.0	3,600
5.0	102	8.4	692	11.8	1,547	19.0	3,950
5.2	122	8.6	738	12.0	1,604	20.0	4,300
5.4	142	8.8	784	12.2	1,663	21.0	4,650
5.6	162	9.0	830	12.4	1,722	22.0	5,000
5.8	192	9.2	880	12.6	1,782	23.0	5,350
6.0	222	9.4	930	12.8	1,841	24.0	5,700
6.2	252	9.6	980	13.0	1,900	25.0	6,050
6.4	282	9.8	1,030	13.2	1,960	26.0	6,400
6.6	316	10.0	1,080	13.4	2,020	27.0	6,800
6.8	352	10.2	1,130	13.6	2,080	28.0	7,220
7.0	390	10.4	1,181	13.8	2,140	29.0	7,730
7.2	430	10.6	1,233	14.0	2,200	30.0	8,300

Estimated monthly discharge of Solomon River at Niles, Kans.

[Drainage area, 6,815 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	152	94	106	6,517	0.02	0.02
ebruary	142	102	119	6,608	.02	.02
arch	207	38	101	6,210	.02	.02
pril	152	54	89	5,296	.01	.01
ay	1,415	38	285	17,524	.04	.05
une	6,155	316	1,392	82,830	.20	.22
uly	7,040	252	2,492	153,227	.37	.43
ugust	2,375	299	847	52,080	.12	.14
eptember	7,040	132	1,392	82,830	.20	22
ctober	7,780	761	2,263	139,145	.33	38
ovember	855	470	601	35,764	.09	.10
ecember	490	316	402	24,718	.06	.07
The year	7,780	38	841	612,749	.12	1.68

SALINE RIVER NEAR SALINA, KANS.

The station, established May 4, 1897, is located at a bridge 4.5 miles northeast of Salina, near the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. Bench mark No. 1 is a nail in an elm tree 2 feet in diameter on the north side of the river and 6 feet west of the bridge. Its elevation is 22.90 feet above gage datum. Bench mark No. 2 is six nails driven into a 16-inch box-elder tree on the north side of the river and 35 east of the bridge. Its elevation is 22.90 feet above gage datum. The channel is straight for a short distance above and below the station. Both banks are high and not liable to overflow. The bed of the stream is sand and mud. The observer is Charley Tressin.

Discharge measurements of Saline River near Salina, Kans.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 6	W. G. Russell	4.00	22
April 30	do	3.30	23
May 11	do	3.20	24
June 2	do	4.70	116
June 11	do	6.80	326
July 2	do	17.40	2,017
July 23	do	4.80	131
September 30	do	24.50	3,822
October 2	do	21.10	2,664
November 29	do	6.10	231

Daily gage height, in feet, of Saline River near Salina, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.70	(a)	4.10	3.60	3.40	5.70	15.80	6.10	9.00	24.50	7.20	6.10
2	3.70	a 4.10	4.30	3.50	3.40	4.60	18.20	5.50	13.50	20.90	7.20	6.10
3	3.80	(a)	4.30	3.60	3.30	4.20	20.20	5.20	12.00	10.80	7.70	6.10
4	3.90	a 4.00	3.80	3.50	3.20	4.30	20.30	5.00	8.60	15.30	7.60	6.00
5	4.20	(a)	3.80	3.50	[illegible]	9.10	10.50	5.00	7.50	15.70	7.20	6.10
6	4.00	a 4.00	3.60	3.40	[illegible]	12.00	8.90	4.80	6.60	15.00	7.00	6.00
7	4.00	(a)	3.70	3.60	[illegible]	15.80	7.90	4.70	6.20	16.10	6.90	5.70
8	4.10	a 4.10	3.90	3.40	[illegible]	16.90	14.50	4.60	5.90	16.90	6.70	5.50
9	4.10	a 4.10	3.90	3.40	3.40	13.90	9.50	5.70	5.70	15.00	6.80	5.80
10	4.20	(a)	3.70	3.50	3.30	8.40	16.10	5.20	5.50	11.60	6.70	5.70
11	4.00	a 4.20	3.60	3.40	3.20	6.80	10.80	7.20	5.30	10.70	6.70	5.5[illegible]
12	4.00	(a)	3.90	3.40	[illegible]	8.20	7.40	9.50	5.20	10.00	6.60	5.[illegible]
13	4.10	a 4.10	3.60	3.50	3.30	7.30	6.20	12.00	5.00	9.60	6.70	5.[illegible]
14	4.20	(a)	3.60	3.50	[illegible]	7.20	6.60	7.40	5.00	10.70	6.70	6.[illegible]

a Frozen.

Daily gage height, in feet, of Saline River near Salina, Kans.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	4.00	a 4.10	3.60	3.40	3.10	12.10	6.00	6.20	4.90	15.20	6.60	6.25
.....	4.20	a 4.20	3.60	3.40	3.20	12.50	5.70	5.50	4.90	17.10	6.60	6.20
.....	4.20	(a)	3.70	3.50	3.20	13.50	5.40	5.00	4.90	16.00	6.60	6.30
.....	4.20	a 4.20	3.60	3.40	3.10	14.40	5.30	4.70	4.80	10.80	6.40	6.20
.....	4.30	(a)	3.40	3.40	3.10	11.00	5.10	5.20	4.80	9.60	6.40	5.90
.....	4.50	(a)	3.60	3.30	3.20	8.40	5.10	5.10	4.80	9.10	6.40	5.60
.....	4.00	a 3.90	3.50	3.40	3.50	14.90	4.80	5.30	4.70	8.70	6.30	5.80
.....	4.00	a 3.60	3.40	3.50	4.00	14.50	4.90	6.20	5.00	8.40	6.30	5.90
.....	4.00	3.80	3.50	3.40	4.00	12.70	4.80	10.00	12.00	8.20	6.30	6.05
.....	4.00	3.60	3.50	3.30	3.50	7.90	4.80	14.40	17.80	8.10	6.30	5.95
.....	4.10	3.60	3.60	3.30	7.20	7.50	4.70	14.00	17.50	7.90	6.20	5.90
.....	a 4.20	3.80	3.60	3.50	7.50	6.80	4.90	15.40	18.00	7.80	6.30	6.10
.....	(a)	3.90	3.60	3.40	6.70	6.30	4.80	16.70	19.60	7.70	6.20	6.35
.....	a 4.30	3.80	3.60	3.20	7.00	6.30	4.90	17.00	21.40	7.50	6.20	5.85
.....	(a)	.....	3.60	3.30	9.70	13.10	4.70	10.00	23.40	7.40	6.10	5.70
.....	a 4.00	.....	3.60	3.10	7.20	13.70	7.50	7.50	24.50	7.30	6.10	5.60
.....	a 4.10	.....	3.60	.....	5.80	.....	6.40	6.90	.....	7.20	.....	5.65

a Frozen.

Rating table for Saline River near Salina, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.2	28	6.8	320	10.4	796	14.0	1,370
3.4	34	7.0	340	10.6	824	14.5	1,460
3.6	41	7.2	364	10.8	852	15.0	1,550
3.8	50	7.4	388	11.0	880	15.5	1,640
4.0	60	7.6	412	11.2	910	16.0	1,730
4.2	70	7.8	436	11.4	940	16.5	1,820
4.4	80	8.0	460	11.6	970	17.0	1,910
4.6	100	8.2	488	11.8	1,000	17.5	2,000
4.8	120	8.4	516	12.0	1,030	18.0	2,090
5.0	140	8.6	544	12.2	1,064	18.5	2,180
5.2	160	8.8	572	12.4	1,098	19.0	2,270
5.4	180	9.0	600	12.6	1,132	19.5	2,360
5.6	200	9.2	628	12.8	1,166	20.0	2,450
5.8	220	9.4	656	13.0	1,200	20.5	2,545
6.0	240	9.6	684	13.2	1,234	21.0	2,640
6.2	260	9.8	712	13.4	1,268	22.0	2,860
6.4	280	10.0	740	13.6	1,302	23.0	3,170
6.6	300	10.2	768	13.8	1,336	24.0	3,620

Estimated monthly discharge of Saline River near Salina, Kans.

(Drainage area, 3,311 square miles.)

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in
1902.						
January	90	45	64	3,935	0.019	
February	70	41	60	3,332	.018	
March	75	34	45	2,767	.014	
April	41	25	35	2,083	.011	
May	698	25	112	6,886	.034	
June	1,892	70	792	47,127	.239	
July	2,507	110	621	38,184	.188	
August	1,910	100	512	31,482	.155	
September	3,920	110	874	52,007	.264	
October	3,920	364	1,089	66,960	.329	
November	424	250	305	18,159	.092	
December	275	190	234	14,388	.071	
The year	3,920	25	395	287,310	.120	

SMOKY HILL RIVER AT ELLSWORTH, KANS.

The gaging station, established April 17, 1895, is located a highway bridge on Douglass avenue, Ellsworth, Kans. The ga an inclined ash timber spiked to a post driven in the bed of the and bolted to an iron post on the bridge pier. The bench mark nail driven into the base of a large box-elder tree near the sout corner of the bridge, 90 feet from the gage, and its elevation is feet above the zero of the gage. A slope gage is spiked to th Louis and San Francisco Railroad bridge 2,536 feet upstream, a referred to the same datum. The channel is nearly straight abov below the gage, and the bed is sandy and shifting. The observ Thomas Coyne.

Discharge measurements of Smoky Hill River at Ellsworth, Kans.

Date.	Hydrographer.	Gage height.	Disc
1902.		*Feet.*	*Secon*
March 27	W. G. Russell	1.00	
June 23	do	6.20	
June 24	do	4.50	
August 18	do	1.40	
August 28	do	3.50	

Daily gage height, in feet, of Smoky Hill River at Ellsworth, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	[a] 1.20	[a] 0.80	1.50	0.95	0.75	1.30	5.20	2.90	3.00	3.60	1.80	1.25
2	[a] 1.20	[a] .80	1.40	.95	.75	1.20	4.60	2.75	2.80	3.40	1.85	1.25
3	[a] 1.20	[a] .80	1.30	.90	.75	1.20	4.30	2.60	2.70	3.60	1.85	1.20
4	[a] 1.20	[a] .80	1.20	.90	.75	2.20	3.90	2.50	2.60	4.10	1.80	1.20
5	[a] .90	[a] .80	1.10	.90	.75	1.70	3.40	2.30	2.40	4.20	1.80	1.20
6	[a] .90	[a] .80	1.10	.90	.75	1.50	3.00	2.10	2.30	4.00	1.75	1.20
7	[a] .90	[a] .80	1.00	.90	.70	1.30	2.80	2.00	2.20	3.80	1.70	1.20
8	[a] .90	[a] .80	1.00	.85	.70	1.25	3.80	2.25	2.00	3.50	1.60	1.15
9	[a] .90	[a] .85	1.00	.85	.70	1.20	3.40	2.20	1.90	3.30	1.60	1.15
10	[a] .90	[a] .85	.95	.85	.70	1.20	3.00	1.95	1.85	3.10	1.55	1.15
11	[a] .90	[a] .85	.95	.85	.70	1.15	6.70	1.80	1.80	2.90	1.50	1.15
12	[a] .90	[a] .90	.95	.80	.70	1.10	5.60	1.80	1.70	2.70	1.60	1.10
13	[a] .90	[a] .90	.90	.80	.70	3.00	5.00	1.75	1.70	2.50	1.65	1.10
14	[a] .90	[a] .90	.90	.80	.85	2.00	4.50	2.20	1.65	2.80	1.70	1.10
15	[a] .85	[a] .90	.90	.80	.80	1.70	3.50	2.00	1.60	3.00	1.65	1.20
16	[a] .85	[a] .95	90	80	.80	2.50	2.70	1.80	1.60	2.60	1.65	1.20
17	[a] .85	[a] .95	85	80	.75	2.30	2.50	1.60	1.55	2.60	1.65	1.20
18	[a] .85	[a] 1.10	85	80	.80	2.10	2.20	1.40	1.50	2.50	1.60	1.20
19	.85	[a] 1.20	85	.80	.85	2.10	2.00	1.30	1.50	2.35	1.60	1.30
20	.85	[a] 1.20	85	75	.85	8.75	1.90	1.25	1.50	2.30	1.60	1.40
21	.85	[a] 1.30	90	75	1.60	5.50	1.80	3.80	1.50	2.20	1.55	1.40
22	.80	[a] 1.50	90	.85	2.20	4.90	1.80	6.50	1.65	2.20	1.55	1.30
23	.80	1.10	90	.85	2.20	6.00	1.70	8.30	3.00	2.15	1.50	([a])
24	.80	1.20	95	.85	2.00	4.50	1.65	12.00	12.60	2.10	1.50	([a])
25	[a] .80	1.20	95	.80	1.80	3.80	3.00	6.50	9.00	2.00	1.45	1.40
26	[a] .80	1.30	2.15	.80	3.05	3.50	2.60	5.00	7.80	2.00	1.40	([a])
27	[a] .80	1.50	1.00	80	1.70	3.20	2.40	4.20	6.20	2.00	1.35	([a])
28	[a] .80	1.50	1.00	.80	1.50	3.00	2.20	3.50	5.20	1.95	1.30	([a])
29	[a] .80	.....	95	80	1.50	5.40	2.00	3.30	4.60	1.90	1.25	([a])
30	[a] .80	.....	95	80	1.50	5.00	3.40	3.10	3.90	1.85	1.25	([a])
31	[a] .80	.....	95		1.45	.....	3.20	3.80	.....	1.85	.....	([a])

[a] River frozen.

Rating table for Smoky Hill River at Ellsworth, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.6	9	2.6	485	4.6	1,670	6.6	3,190
0.8	17	2.8	575	4.8	1,810	6.8	3,345
1.0	25	3.0	675	5.0	1,950	7.0	3,500
1.2	55	3.2	780	5.2	2,105	8.0	4,275
1.4	85	3.4	900	5.4	2,260	9.0	5,050
1.6	125	3.6	1,020	5.6	2,415	10.0	5,825
1.8	175	3.8	1,140	5.8	2,570	11.0	6,600
2.0	235	4.0	1,260	6.0	2,725	12.0	7,375
2.2	310	4.2	1,390	6.2	2,880		
2.4	395	4.4	1,530	6.4	3,035		

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans.

[Drainage area, 7,980 square miles.]

Month.	Discharge in second-feet.			Run-off.		
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in
1902.						
January	55	17	24	1,475	0.003	
February	100	17	38	2,110	.005	
March	290	19	39	2,398	.005	
April	23	15	18	1,071	.002	
May	700	13	87	5,349	.011	
June	4,856	40	821	48,853	.103	
July	3,267	137	891	54,785	.112	
August	7,375	62	1,021	62,779	.128	
September	7,840	100	1,033	61,468	.130	
October	1,390	187	588	36,155	.074	
November	187	62	125	7,438	.016	
December	85	40	64	3,935	.008	
The year	7,840	13	396	287,816	.050	

Miscellaneous measurements in Kansas River drainage basin in Nebraska.

[Made by J. C. Stevens, B. E. Forbes, H. O. Smith, Frank Dobson.]

Date.	Stream.	Locality.	Discharge.
1902.			Sec
April 5	Blue River	Seward	
April 18	do	Crete	
Do	do	do	
September 16	do	Wymore	
July 2	Crooked Creek	Sec. 1, T. 1, R. 11 W	a
June 10	Center Creek	Sec. 36, T. 2, R. 15 W	
Do	do	Sec. 7, T. 1, R. 15 W	
April 25	Frenchman River	Culbertson	
June 13	do	Enders	
September 18	d	Culbertson	
June 10	Lost Creek	Sec. 10, T. 1, R. 15 W	
April 25	Republican	Culbertson	
April 26	do	Ives	
Do	do	Stratton	
Do	do	Haigler	
April 27	do	Oxford	

Miscellaneous measurements in Kansas River drainage basin in Nebraska—Continued.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
April 27	Republican	McCook	137
June 10	do	Franklin	743
June 12	do	Benkleman	35
September 17	do	Oxford	37
Do	do	McCook	29
Do	do	Benkleman	45
September 18	do	Culbertson	41
June 12	Republican, South Fork	State Line	32.8
September 17	do	Benkleman	31.6
April 26	Rock Creek	Ives	9.9

[a] Flood.

ARKANSAS RIVER DRAINAGE BASIN.

The Arkansas River rises in the central part of Colorado, flows south for about 70 miles, then east for 50 miles, increased by many small mountain streams. At Canyon, Colo., it emerges from the Rocky Mountain front and takes a general easterly direction across the great plains of Colorado, where most of the water is diverted for irrigation. It flows east across Kansas to the center of the State, thence southeast through Indian Territory and Arkansas into the Mississippi River, about 25 miles north of Greenville, Miss. Throughout the mountainous area above Canyon the discharge increases, but as soon as the river emerges onto the Great Plains the water is gradually diverted by lines of canals, so that by the time the Kansas line is reached the river is usually dry during the summer. Among its tributaries the Neosho (called the Grand in Indian Territory) and the Verdigris rivers drain southeastern Kansas and flow south in nearly parallel courses, joining the Arkansas about 3 miles apart, west of Tahlequah, Ind. T. The Walnut River is a small tributary from the north, flowing into the Arkansas at Arkansas City, Kans. The north fork of the Canadian River rises in the northeastern part of New Mexico, and flows east through Oklahoma and Indian Territory into the Canadian River about 40 miles above its mouth. The following is a list of the stations in the Arkansas River drainage basin:

Canadian River (North Fork) near Elreno, Okla.
Neosho River at Iola, Kans.
Verdigris River near Liberty, Kans.
Walnut River at Arkansas City, Kans.
Arkansas River at Arkansas City, Kans.

Arkansas River at Hutchinson, Kans.
Arkansas River at Dodge City, Kans.
Arkansas River at Syracuse, Kans.
Arkansas River at Barton, Colo.
Arkansas River near Rockyford, Colo.
Arkansas River near Nepesta, Colo.
Arkansas River at Pueblo, Colo.
Arkansas River near Canyon, Colo.
Arkansas River at Salida, Colo.

CANADIAN RIVER (NORTH FORK) NEAR ELRENO, OKLA.

This station was established October 27, 1902, by W. G. Russell, and is located at the highway bridge, 2 miles north of Elreno, Okla. The gage is of the usual wire type, with a scale board graduated to feet and tenths, and nailed to the railing of the bridge. The bench mark is the top of a steel cylinder on the north side of the bridge. Its elevation is 11.3 feet above the zero of the gage. The initial point for sounding is on the right bank. The channel both above and below the station is straight for about 200 feet; the right bank is high and the left bank is low; both banks are liable to overflow. The bed of the stream is sandy, and somewhat shifting. The observer is G. G. Sudermann, who reads the gage once daily.

The following discharge measurement was made in 1902:

October 27: Gage height, 2.00 feet; discharge, 23 second-feet.

Daily gage height, in feet, of Canadian River (North Fork), near Elreno, Okla.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	2.00	2.60	12	.....	2.10	2.50	23	.....	2.50	2.60
2	.....	2.20	2.50	13	.....	2.30	2.50	24	.....	3.00	2.60
3	.....	2.10	2.40	14	.....	2.20	2.80	25	.....	2.80	2.70
4	.....	2.10	2.40	15	.....	2.20	2.80	26	.....	2.60	2.80
5	.....	2.10	2.40	16	.....	2.20	2.70	27	2.00	2.50	2.80
6	.....	2.10	2.50	17	.....	2.30	2.70	28	2.00	2.50	2.80
7	.....	2.10	2.50	18	.....	2.30	2.70	29	2.00	2.50	2.40
8	.....	2.10	2.50	19	.....	2.30	2.60	30	2.00	2.50	2.40
9	.....	2.10	2.50	20	.....	2.30	2.60	31	2.00	.....	2.60
10	.....	2.10	2.50	21	.....	3.45	2.60				
11	.....	2.10	2.50	22	.....	2.80	2.60				

NEOSHO RIVER AT IOLA, KANS.

The station was established in July, 1895, and is located at the highway bridge 1 mile west of the city of Iola, Kans. The gage is fastened to the head gates of the flume about 90 feet above the bridge. The bench mark is the heads of three large nails driven into the cross-piece of the flume, and is 13.30 feet above the datum of the gage.

The observer is Thomas J. Staley.

The following discharge measurements were made by W. G. Russell during 1902:

April 26: Gage height, 3.00 feet; discharge, 512 second-feet.
May 29: Gage height, 12.00 feet; discharge, 15,216 second-feet.
June 19: Gage height, 4.50 feet; discharge, 1,312 second-feet.
July 29: Gage height, 7.70 feet; discharge, 6,995 second-feet.
August 25: Gage height, 16.50 feet; discharge, 25,246 second-feet.

Daily gage height, in feet, of Neosho River at Iola, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	2.00	2.70	3.15	2.90	4.00	8.00	4.50	5.15	13.50	4.65	3.35	3.60
.....	2.00	2.70	4.00	2.90	3.50	7.50	4.50	4.25	12.10	4.00	3.30	3.65
.....	2.10	2.70	3.50	2.90	3.50	5.75	4.50	3.00	10.50	4.50	3.35	4.85
.....	2.20	2.70	3.60	2.90	3.30	5.50	4.50	2.85	6.25	10.00	3.30	5.70
.....	2.30	2.70	3.00	2.90	3.30	13.00	4.50	2.80	5.25	14.25	3.15	4.50
.....	2.30	2.70	3.00	2.90	6.10	15.25	4.50	2.65	6.15	11.75	3.00	3.95
.....	2.50	2.70	3.00	2.90	5.25	16.75	4.50	2.50	7.35	11.75	3.00	3.90
.....	2.50	2.70	3.00	2.85	3.50	17.90	5.00	2.50	8.10	10.75	3.00	3.65
.....	2.50	2.70	3.00	2.80	3.00	17.90	5.00	2.40	6.75	8.75	3.00	3.50
.....	2.50	2.70	3.00	2.80	3.00	20.50	5.00	2.40	5.90	6.65	3.00	3.50
.....	2.50	2.80	2.90	2.80	2.90	21.25	4.70	2.40	5.25	6.10	3.00	3.50
.....	2.50	2.80	3.00	2.80	2.80	15.50	4.70	2.40	4.40	6.20	3.00	3.50
.....	2.50	2.80	3.10	2.80	2.80	5.55	4.50	2.40	3.50	5.50	3.00	3.50
.....	2.50	2.80	3.00	2.80	2.80	5.00	4.50	2.40	3.40	5.40	5.00	3.60
.....	2.50	2.80	2.80	2.80	2.80	5.00	4.25	2.90	3.40	5.30	5.00	4.50
.....	2.50	3.00	2.80	2.80	4.25	5.00	4.00	2.90	3.40	5.20	4.50	4.65
.....	2.50	3.00	2.90	2.80	6.55	5.00	4.00	2.50	3.00	5.50	4.30	3.85
.....	2.50	3.00	2.90	2.80	5.20	4.50	4.00	2.50	3.00	5.50	4.30	3.90
.....	2.50	3.00	2.70	2.80	4.25	4.50	4.50	3.00	3.10	5.20	4.20	4.00
.....	2.60	3.00	2.70	2.80	3.25	11.50	6.00	5.85	3.20	5.40	4.20	7.25
.....	2.60	3.00	3.00	2.80	4.50	15.50	5.00	9.75	3.50	5.50	4.00	8.00
.....	2.70	3.00	3.00	2.80	11.50	15.00	4.00	11.50	6.00	4.75	3.80	7.00
.....	2.70	3.00	2.80	2.80	12.00	10.50	4.00	13.50	8.50	4.50	3.80	6.50
.....	2.70	3.00	2.80	3.00	12.75	8.25	4.00	16.25	8.50	4.25	3.70	6.00
.....	2.75	3.00	2.90	4.00	12.35	7.65	3.50	16.25	12.25	4.20	3.70	5.00
.....	2.70	3.15	2.90	3.00	13.50	5.50	3.50	15.25	7.75	4.50	3.70	4.65
.....	2.70	3.60	2.90	3.00	12.50	5.00	3.50	15.25	6.00	4.00	3.60	4.50
.....	2.70	3.60	3.00	6.50	12.60	4.50	4.00	11.15	5.00	4.00	3.60	4.50
.....	2.70	.....	3.00	5.75	12.00	4.50	7.55	7.50	5.00	3.65	3.60	4.20
.....	2.70	.....	2.80	4.25	9.00	4.50	6.00	5.25	4.90	3.50	3.60	4.00
.....	2.70	.....	2.80	.....	6.25	.....	5.40	12.25	.....	3.40	.....	3.90

Rating table for Neosho River at Iola, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Dischar
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-f*
2.0	190	4.8	2,360	7.6	6,780	11.0	13,1
2.2	260	5.0	2,600	7.8	7,140	11.5	14,1
2.4	330	5.2	2,900	8.0	7,500	12.0	15,2
2.6	400	5.4	3,200	8.2	7,860	12.5	16,3
2.8	490	5.6	3,500	8.4	8,220	13.0	17,4
3.0	580	5.8	3,800	8.6	8,580	13.5	18,5
3.2	700	6.0	4,100	8.8	8,940	14.0	19,6
3.4	850	6.2	4,420	9.0	9,300	15.0	21,8
3.6	1,000	6.4	4,740	9.2	9,660	16.0	24,0
3.8	1,200	6.6	5,060	9.4	10,020	17.0	26,2
4.0	1,400	6.8	5,380	9.6	10,380	18.0	28,4
4.2	1,640	7.0	5,700	9.8	10,740	19.0	30,6
4.4	1,880	7.2	6,060	10.0	11,100	20.0	32,8
4.6	2,120	7.4	6,420	10.5	12,100	21.0	35,0

Estimated monthly discharge of Neosho River at Iola, Kans.

[Drainage area, 3,670 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	De in
1902.						
January	467	190	370	22,750	0.10	
February	1,000	445	549	30,470	.15	
March	1,400	445	601	36,954	.16	
April	4,900	490	836	49,745	.23	
May	18,500	490	5,585	343,408	1.52	
June	35,550	2,000	11,694	695,841	3.19	
July	6,690	925	2,169	133,367	.59	
August	24,550	330	6,382	392,414	1.74	
September	18,500	580	4,962	295,259	1.35	
October	20,150	850	4,689	288,315	1.28	
November	2,600	580	1,119	66,585	.30	
December	7,500	925	2,227	136,933	.61	
The year	35,550	190	3,432	2,492,041	.94	

VERDIGRIS RIVER NEAR LIBERTY, KANS.

The station was established in August, 1895, and is located wagon bridge about 250 feet below McTaggart's mill dam, ab miles southwest of the town of Liberty, Kans. The gage is a ve

ıber fastened to the floor of the mill. Bench mark No. 1 is the ıds of three large nails in the flume, and is at an elevation of 12.46 ɛt above the zero of the gage. Bench mark No. 2 is the head of a ke in the root of a cottonwood tree 40 feet south of the gage, and at an elevation of 10.98 feet above gage datum. The bed is rocky, nposed of gravel and subject to very little change. In 1900 a new nch mark was established, consisting of 3 nails driven horizontally o a root on the river side of a cottonwood tree 40 feet south of the ge, the nails being 8 inches below a sandstone rock which protrudes om a hollow in the tree. Its elevation is 11.88 feet above the zero the old gage.

The observer is C. Fienen.

During 1902 the following discharge measurements were made by . G. Russell:

April 27: Gage height, 3.10 feet; discharge, 284 second-feet.
May 30: Gage height, 5.50 feet; discharge, 1,822 second-feet.
June 20: Gage height, 9.75 feet; discharge, 6,192 second-feet.
August 24: Gage height, 8.70 feet; discharge, 5,136 second-feet.

Daily gage height, in feet, of Verdigris River near Liberty, Kans.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	2.00	1.90	3.85	3.00	2.60	5.20	5.70	3.60	14.25	4.80	3.20	3.80
.....	2.00	1.90	3.75	2.90	3.30	8.35	5.30	3.25	14.00	4.60	3.25	4.15
.....	2.00	1.90	3.70	2.90	4.25	7.25	4.45	3.05	7.00	4.65	3.50	6.20
.....	2.00	1.90	3.45	2.90	3.30	11.90	4.05	2.80	4.65	6.80	4.10	5.90
.....	2.00	1.90	2.80	2.90	5.25	26.25	3.75	2.65	4.20	15.20	5.30	5.35
.....	2.00	1.90	2.70	2.90	6.95	31.75	3.55	2.60	7.90	16.85	4.30	4.65
.....	2.00	1.90	2.60	2.80	9.45	33.37	3.35	2.50	10.75	11.05	3.95	4.25
.....	2.00	1.90	2.55	2.70	6.20	32.10	6.40	2.50	7.50	6.10	3.85	4.10
.....	2.00	1.90	2.50	2.70	5.00	29.50	9.40	2.70	4.75	5.40	3.80	4.00
.....	2.00	1.90	2.40	2.70	4.05	13.25	6.10	3.10	3.75	4.95	3.70	4.00
.....	2.00	1.90	2.40	2.65	3.60	6.25	5.80	2.95	3.60	4.75	3.55	4.00
.....	1.90	1.90	2.50	2.65	3.35	5.40	4.35	2.95	3.40	4.55	3.45	4.00
.....	1.90	1.90	2.40	2.60	3.25	4.90	4.10	2.75	3.35	4.40	3.20	4.00
.....	1.90	1.90	2.40	2.60	3.05	4.70	3.85	2.60	3.30	4.25	12.70	4.85
.....	1.90	1.90	2.40	2.60	3.05	6.65	3.65	2.60	3.15	4.10	14.20	11.25
.....	1.90	1.90	2.80	2.60	3.15	8.30	3.45	2.50	3.00	4.05	7.90	10.10
.....	1.90	1.90	2.75	2.65	2.90	4.90	3.30	2.40	3.05	3.95	5.80	6.40
.....	1.90	1.90	2.70	2.65	2.75	5.35	3.20	2.40	3.05	3.75	5.00	5.40
.....	1.90	1.90	2.60	2.60	2.80	10.65	4.30	2.30	3.00	3.65	4.65	5.40
.....	1.90	1.90	2.50	2.60	2.90	12.05	4.05	2.25	3.50	3.60	4.50	7.05
.....	1.90	1.90	2.50	2.60	3.40	14.10	5.35	2.70	4.75	3.60	4.40	10.75
.....	1.90	1.90	2.50	2.55	13.30	15.05	4.40	3.45	5.25	3.60	4.35	8.45
.....	1.90	1.90	2.60	2.55	22.70	14.90	3.90	3.65	5.40	3.55	4.25	6.10
.....	1.90	2.25	3.55	2.65	28.05	9.10	3.95	7.90	13.00	3.45	4.45	5.45
.....	1.90	2.75	3.40	3.60	28.67	5.15	3.45	10.00	20.75	3.40	4.65	5.10
.....	1.90	5.60	3.35	3.90	25.25	4.70	3.00	11.95	17.90	3.30	4.55	4.75
.....	1.90	5.05	3.55	3.10	22.30	4.40	2.90	8.25	7.00	3.25	4.40	4.55
.....	1.90	4.70	3.70	2.85	19.00	4.20	2.90	5.40	5.75	3.20	4.30	4.30
.....	1.90	.....	3.50	2.65	9.10	4.75	2.95	4.70	5.15	3.20	3.95	4.30
.....	1.90	.....	3.25	2.60	5.40	6.05	3.80	3.70	5.00	3.20	3.85	4.30
.....	1.90	.....	3.15	.....	5.00	.....	3.80	8.20	.....	3.20	.....	4.30

Rating table for Verdigris River near Liberty, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.2	2	5.2	1,520	9.2	4,375	18.0	12,300
1.4	5	5.4	1,650	9.4	4,525	19.0	13,500
1.6	10	5.6	1,780	9.6	4,680	20.0	14,700
1.8	27	5.8	1,920	9.8	4,840	21.0	15,900
2.0	55	6.0	2,060	10.0	5,000	22.0	17,150
2.2	90	6.2	2,200	10.2	5,160	23.0	18,500
2.4	140	6.4	2,340	10.4	5,320	24.0	19,900
2.6	205	6.6	2,480	10.6	5,480	25.0	21,300
2.8	280	6.8	2,620	10.8	5,640	26.0	22,700
3.0	368	7.0	2,760	11.0	5,801	27.0	24,100
3.2	464	7.2	2,901	11.2	5,963	28.0	25,500
3.4	560	7.4	3,043	11.4	6,126	29.0	26,900
3.6	660	7.6	3,188	11.6	6,290	30.0	28,300
3.8	760	7.8	3,334	11.8	6,454	31.0	29,700
4.0	860	8.0	3,480	12.0	6,619	32.0	31,100
4.2	960	8.2	3,626	13.0	7,458	33.0	32,500
4.4	1,060	8.4	3,775	14.0	8,300	34.0	33,950
4.6	1,164	8.6	3,925	15.0	9,150	35.0	35,450
4.8	1,280	8.8	4,075	16.0	10,100	36.0	36,950
5.0	1,400	9.0	4,225	17.0	11,150		

Estimated monthly discharge of Verdigris River near Liberty, Kans.

[Drainage area, 3,067 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	55	40	45	2,767	0.01	0.0
February	1,780	40	204	11,330	.07	.0
March	785	140	357	21,951	.12	.1
April	810	187	268	15,947	.09	.1
May	26,438	205	5,395	331,718	1.76	2.0
June	33,018	960	7,893	469,666	2.57	2.8
July	4,525	320	1,050	64,562	.34	.3
August	6,577	100	1,051	64,623	.34	.3
September	15,650	368	2,935	174,645	.96	1.0
October	11,080	464	1,706	104,898	.56	.6
November	8,470	464	1,598	95,088	.52	.5
December	6,433	685	1,852	113,875	.60	.6
The year	33,018	40	2,030	1,471,070	.66	8.9

WALNUT RIVER AT ARKANSAS CITY, KANS.

This station was established September 21, 1902, by W. G. Russell, nd is located on the Madison avenue highway bridge one-half mile ast of Arkansas City, Kans. The gage is of the usual wire type, with he scaleboard graduated to feet and tenths; it is read daily by D. T. Burton. The bench mark is the lower edge of the fifth rivet from the op in the upper row on the fourth section of the west side of the outh pier. The initial point for sounding is on the right bank. The hannel both above and below the station is straight, and the river is luggish; both the right and left bank are high; the bed of the stream s sandy and shifting.

The following discharge measurements were made during 1902 by W. G. Russell:

September 24: Gage height, 10.15 feet; discharge, 3,899 second-feet.
October 20: Gage height, 4.90 feet; discharge, 182 second-feet.

Daily gage height, in feet, of Walnut River at Arkansas City, Kans.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.														
.....		5.30	5.05	4.45	12	.....	4.45	4.60	4.45	23	.....	4.10	4.20	5.90
.....		5.65	5.00	4.40	13	.....	4.40	4.70	4.40	24	10.30	4.20	4.30	6.15
.....		6.10	4.45	4.30	14	.....	4.30	4.60	4.65	25	10.40	4.00	4.40	6.20
.....		5.65	4.60	4.40	15	.....	4.40	4.40	5.25	26	7.30	4.30	4.30	6.60
.....		8.75	5.00	4.30	16	.....	4.10	4.30	5.40	27	6.40	4.20	4.30	5.75
.....		9.45	5.10	4.30	17	.....	4.10	4.40	5.50	28	6.10	4.00	4.20	5.70
.....		6.55	5.05	4.40	18	.....	4.00	4.50	5.60	29	6.00	4.10	4.30	5.65
.....		6.00	5.10	4.40	19	.....	4.20	4.60	5.60	30	4.40	4.05	4.40	5.60
.....		5.20	5.20	4.30	20	.....	4.10	4.50	5.55	31	.....	4.30	.....	5.70
.....		5.10	5.10	4.30	21	.....	4.30	4.40	5.70					
.....		5.00	5.00	4.40	22	.....	4.20	4.45	5.80					

ARKANSAS RIVER AT ARKANSAS CITY, KANS.

This station was established September 23, 1902, by W. G. Russell. : is located on the Chestnut avenue highway bridge, one-half mile est of Arkansas City, Kans. The gage is a painted staff graduated) feet and tenths, spiked to the west side of the south pile of the econd bent on Chestnut avenue. The bench mark is the top of the cap n the pile which carries the gage. Its elevation is 17.2 feet above zero f the gage. The initial point for sounding is on the left bank. The hannel is straight for about 200 feet both above and below the station; oth banks are low and liable to overflow; the bed of the river is andy and shifting. The observer is D. T. Burton, who reads the age daily.

The following discharge measurements were made during 1902:

September 23: Gage height, 4.70 feet; discharge, 1,008 second-feet.
October 20: Gage height, 3.80 feet; discharge, 218 second-feet.

Daily gage height, in feet, of Arkansas River at Arkansas City, Kans.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.				
1	.....	4.10	4.40	3.40	17	.....	4.00	3.50	3.70
2	.....	4.30	4.10	3.40	18	.....	3.20	3.60	3.80
3	.....	4.40	3.70	3.50	19	.....	3.00	3.70	3.70
4	.....	4.45	3.80	3.40	20	.....	3.20	3.70	3.70
5	.....	4.50	3.60	3.30	21	.....	3.10	3.60	3.60
6	.....	4.55	3.30	3.40	22	.....	3.30	3.50	3.55
7	.....	4.50	3.40	3.45	23	4.70	3.40	3.60	3.55
8	.....	4.45	3.45	3.45	24	4.30	3.55	3.50	3.70
9	.....	4.55	3.65	3.50	25	4.20	4.10	3.40	3.10
10	.....	4.30	3.60	3.40	26	4.10	4.00	3.50	3.00
11	.....	4.55	3.50	3.45	27	4.10	4.10	3.60	2.70
12	.....	4.40	3.60	3.40	28	4.10	4.20	3.50	2.80
13	.....	4.20	3.70	3.40	29	4.00	4.10	3.40	2.75
14	.....	4.30	3.60	3.50	30	4.05	4.10	3.30	2.65
15	.....	4.10	3.40	3.60	31	.....	4.20	.....	2.65
16	.....	4.15	3.60	3.70					

ARKANSAS RIVER AT HUTCHINSON, KANS.

The Arkansas River, after crossing the Kansas and Colorado State line, is not systematically measured until Hutchinson, in about the center of the State, is reached. The station here was established May 13, 1895, and is located at the wagon bridge at the south end of Main street. The gage consists of an oak timber spiked to a pile a few feet above the bridge. Bench mark No. 1 is the upper crosspiece of the pier guard, with an elevation of 8.35 feet above zero of the gage. Bench mark No. 2 is the top of the iron doorsill of the first brick building next to the river, and its elevation is 8.12 feet above gage datum. The channel is straight for some distance above and below the bridge: the bed is sandy and very shifting, necessitating frequent discharge measurements and soundings. At time of low water the stream subdivides into a number of threads. Measurements of discharge are made from the bridge at times of high water, and at low water they can be made by wading.

The observer is Daniel Lauer.

charge measurements made on Arkansas River at Hutchinson, Kans.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
.....	W. G. Russell.....	1.10	39
.....	.....do	1.50	155
.....	.....do	4.15	5,057
.....	.....do	3.75	3,824
.....	.....do	2.05	550
.....	.....do	2.55	1,066
.....	.....do	2.40	1,117
5.....	.....do	1.20	95

Daily gage height, in feet, of Arkansas River at Hutchinson, Kans.

.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	1.20	1.20	2.00	1.25	1.00	4.42	2.15	1.80	1.70	2.30	1.30	1.10
.....	1.20	2.00	2.00	1.25	1.00	4.60	2.40	1.60	1.70	2.10	1.30	1.10
.....	1.25	(a)	2.00	1.25	1.00	4.12	2.40	1.60	1.60	2.00	1.30	1.10
.....	1.25	2.00	2.00	1.20	1.10	3.72	2.40	1.55	1.50	1.95	1.30	1.10
.....	1.25	2.00	1.80	1.20	1.10	3.57	2.15	1.50	1.55	1.85	1.30	1.10
.....	1.20	2.00	1.60	1.20	1.10	3.05	2.05	1.45	1.60	1.75	1.25	1.10
.....	1.20	(a)	1.50	1.20	1.10	2.82	2.05	1.40	1.65	1.70	1.25	1.10
.....	1.15	2.00	1.40	1.20	1.05	2.70	2.00	1.40	1.45	1.65	1.25	1.20
.....	1.10	1.20	1.35	1.20	1.05	2.62	1.95	1.40	1.45	1.65	1.20	1.30
.....	1.05	(a)	1.30	1.20	1.05	2.52	1.95	1.40	1.40	1.65	1.20	1.30
.....	1.00	1.20	1.30	1.20	1.05	2.45	1.90	1.90	1.40	1.60	1.20	1.30
.....	1.10	1.20	1.25	1.15	1.00	2.40	1.85	2.45	1.35	1.50	1.20	1.30
.....	1.10	.....	1.25	1.15	1.00	2.32	2.10	2.20	1.35	1.50	1.25	1.30
.....	1.05	1.20	1.20	1.15	1.20	2.22	2.50	2.10	1.35	1.50	1.30	1.30
.....	1.05	.....	1.15	1.15	1.30	2.10	2.55	2.00	1.30	1.45	1.25	1.30
.....	1.00	1.20	1.10	1.15	1.20	2.00	2.60	1.95	1.30	1.45	1.20	1.30
.....	1.00	(a)	1.10	1.15	1.25	1.95	2.60	1.85	1.30	1.40	1.20	1.30
.....	1.00	1.20	1.10	1.15	1.20	2.15	2.50	1.80	1.25	1.35	1.20	1.30
.....	1.00	(a)	1.10	1.15	1.15	2.20	2.15	1.75	1.25	1.35	1.20	1.30
.....	1.00	1.20	1.10	1.15	1.15	2.20	1.95	1.75	1.20	1.35	1.20	1.40
.....	1.25	(a)	1.10	1.10	1.30	2.25	1.70	2.45	1.25	1.35	1.20	a1.50
.....	1.25	1.20	1.15	1.10	1.55	2.30	1.70	2.50	1.25	1.35	1.20	a1.50
.....	1.25	2.00	1.20	1.10	2.00	2.25	1.70	2.35	1.35	1.30	1.20	a1.50
.....	1.25	2.00	1.20	1.05	2.00	2.45	1.70	2.40	1.30	1.30	1.20	a1.50
.....	1.20	2.00	1.20	1.05	1.70	2.50	1.75	2.50	1.25	1.30	1.20	a1.50
.....	1.20	2.00	1.25	1.05	1.55	2.40	1.75	2.40	1.25	1.30	1.20	a1.50
.....	(a)	2.00	1.30	1.05	1.40	2.30	1.80	2.35	1.25	1.30	1.10	a1.50
.....	1.20	2.00	1.30	1.00	1.50	2.25	1.90	2.25	2.00	1.30	1.10	1.50
.....	1.20	.....	1.30	1.00	1.45	2.25	2.00	2.10	2.15	1.30	1.10	1.40
.....	(a)	.....	1.30	1.00	1.50	2.15	2.00	2.00	2.30	1.30	1.10	1.40
.....	1.20	.....	1.30	.....	3.90	.....	1.90	1.80	.....	1.30	.....	1.40

a Frozen.

Rating table for Arkansas River at Hutchinson, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.8	20	1.8	325	2.8	1,640	3.8	4,080
.9	30	1.9	400	2.9	1,820	3.9	4,340
1.0	40	2.0	475	3.0	2,000	4.0	4,600
1.1	60	2.1	600	3.1	2,260	4.1	4,860
1.2	80	2.2	725	3.2	2,520	4.2	5,120
1.3	100	2.3	850	3.3	2,780	4.3	5,380
1.4	125	2.4	975	3.4	3,040	4.4	5,640
1.5	150	2.5	1,100	3.5	3,300	4.5	5,900
1.6	200	2.6	1,280	3.6	3,560	4.6	6,160
1.7	250	2.7	1,460	3.7	3,820		

Estimated monthly discharge of Arkansas River at Hutchinson, Kans.

[Drainage area, 34,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	90	40	69	4,243	0.002	0.00
February	475	80	263	14,606	.008	.00
March	475	60	148	9,100	.004	.00
April	90	40	68	4,046	.002	.00
May	4,340	40	254	15,618	.008	.00
June	6,160	438	1,583	94,195	.047	.05
July	1,280	288	605	37,190	.018	.02
August	1,100	125	510	31,359	.015	.01
September	850	80	184	10,949	.005	.00
October	850	100	208	12,789	.006	.00
November	100	60	83	4,939	.002	.00
December	150	60	106	6,518	.003	.00
The year	6,160	40	340	245,552	.010	.13

ARKANSAS RIVER AT DODGE, KANS.

This station was established November 28, 1902, by W. G. Russell, and is located one-fourth mile south of Dodge, on the highway bridge. The gage is a plain staff graduated to feet and tenths, and nailed to the upstream pile of the twelfth bent at the north end of the bridge. The initial point for sounding is on the left bank. The channel both above and below the station is straight for about 100 feet; both banks are low and liable to overflow; the bed of the stream is sandy and shifting. The observer is Alexander Alter, who reads the gage once each day.

The following discharge measurement was made in 1902:

November 28: Gage height, 1.55 feet; discharge, 45 second-feet.

Daily gage height, in feet, of Arkansas River at Dodge, Kans.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.											
1		1.45	9		1.55	17		1.25	25		1.55
2		1.55	10		1.35	18		1.25	26		1.65
3		2.00	11		1.65	19		1.25	27		1.65
4		1.35	12		1.25	20		1.15	28	1.55	1.45
5		1.35	13		1.45	21		1.45	29	1.10	1.65
6		1.25	14		1.65	22		1.55	30	1.45	1.65
7		1.50	15		1.00	23		1.45	31		1.55
8		1.65	16		1.00	24		1.55			

ARKANSAS RIVER AT SYRACUSE, KANS.

This station, established August 21, 1902, by W. G. Russell, is located on the highway bridge 1 mile south of Syracuse, Kans. The gage is a plain staff graduated to feet and tenths, fastened to the east pile of the bent 283 feet south of the north end of the bridge. The initial point for sounding is on the left bank. The channel above and below the station is straight and the water is sluggish. The right bank is low and liable to overflow; the left bank is high, and the bed of the stream is sandy and shifting. The bench mark is on the top of the east end of the first sill at the north end of the bridge. Its elevation is 13.45 feet above the zero of the gage. The gage is read daily by Clyde S. Welborn.

The following discharge measurements were made during 1902:

August 21: Gage height, 2.05 feet; discharge, 99 second-feet.
August 30: Gage height, 3.00 feet; discharge, 909 second-feet.
November 9: Gage height, 1.80 feet; discharge, 42 second-feet.
November 26: Gage height, 1.60 feet; discharge, 19 second-feet.

Daily gage height, in feet, of Arkansas River at Syracuse, Kans.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.					
1	.....	2.70	1.75	1.70	1.8
2	.....	2.70	1.75	1.70	1.7
3	.....	2.65	1.80	1.70	1.7
4	.....	2.55	2.00	1.70	1.8
5	.....	2.50	2.00	1.70	1.7
6	.....	2.50	1.95	1.70	1.7
7	.....	2.45	1.95	1.70	1.8
8	.....	2.45	1.90	1.70	1.8
9	.....	2.40	1.90	1.80	1.8
10	.....	2.35	1.85	1.80	1.8
11	.....	2.30	1.80	1.80	1.8
12	.....	2.25	1.80	1.80	1.8
13	.....	2.15	1.80	1.80	1.8
14	.....	2.05	1.80	1.80	1.8
15	.....	1.95	1.80	1.80	1.8
16	.....	1.95	1.80	(a)	1.8
17	.....	1.95	1.80	.....	1.8
18	.....	1.90	1.80	.....	1.8
19	.....	1.90	1.80	.....	1.8
20	.....	1.90	1.80	.....	1.8
21	2.05	1.90	1.80	.....	1.9
22	2.05	1.85	1.75	.....	2.0
23	2.00	1.85	1.75	.....	2.0
24	2.00	1.85	1.75	.....	2.0
25	1.90	1.80	1.75	.....	2.0
26	2.05	1.80	1.70	1.60	2.0
27	3.05	1.80	1.70	1.80	1.9
28	3.85	1.75	1.70	1.70	2.0
29	3.45	1.75	1.70	1.80	2.1
30	3.00	1.75	1.70	1.80	2.0
31	2.85	.....	1.70	.....	2.0

a No observer.

Rating table for Arkansas River at Syracuse, Kans., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.6	20	2.2	190	2.8	680	3.4	1,315
1.7	30	2.3	250	2.9	780	3.5	1,430
1.8	40	2.4	330	3.0	880	3.6	1,545
1.9	60	2.5	410	3.1	980	3.7	1,660
2.0	80	2.6	500	3.2	1,090	3.8	1,775
2.1	130	2.7	590	3.3	1,200	3.9	1,890

Estimated monthly discharge of Arkansas River at Syracuse, Kans.

[Drainage area, 24,960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
August 21 to 31	.....	.....	[a] 571	[a] 12,459	[a] 0.023	[a] 0.009
September	590	35	197	11,722	.008	.009
October	80	30	43	2,644	.002	.002
November	.....	.....	[b] 34	[c] 2,023	[c] .001	[c] .002
December	130	30	54	3,320	.002	.003

[a] 11 days. [b] 20 days. [c] 30 days.

ARKANSAS RIVER AT BARTON, COLO.

This station was established May 2, 1901, at the railroad bridge one-half mile east of Barton or Byron, which is the name of the railroad station on the Atchison, Topeka and Santa Fe Railway. Throughout this region the bed of the stream is broad and sandy, and the channel is shifting. This point was selected as the most available place for determining, approximately, the discharge of the Arkansas at a point near the Colorado-Kansas line. The rod consists of a vertical 2 by 4 inch piece of timber 7 feet long, nailed to a pile on the downstream side of the railroad bridge at the lowest point in the channel. No bench mark was established, but the rod was spiked at the foot marks to the pile. The channel is extremely shifting, and there may be at times many different channels. The initial point for soundings is the right bank. The observer was Harry Hunt, postmaster at Barton.

The observations at this station were discontinued in May, 1902, for the reason that the channel had changed and the conditions were unfavorable for securing reliable data.

Daily gage height, in feet, of Arkansas River at Barton, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1902.						1902.					
1	1.15	1.30	0.90	0.30	0.10	17	1.30	1.50	0.20	0.20	.....
2	1.20	1.30	.80	.30	.15	18	1.20	1.50	.30	.20	.....
3	1.20	1.40	.80	.20	.15	19	1.20	1.40	.35	.25	.....
4	1.30	1.50	.70	.10	.....	20	1.15	1.40	.35	.25	.....
5	1.30	1.50	.70	.10	.....	21	1.15	1.40	.35	.20	.....
6	1.30	1.50	.50	.05	.....	22	1.10	1.30	.35	.20	.....
7	1.40	1.50	.40	.05	.....	23	1.10	1.30	.45	.20	.....
8	1.40	1.50	.40	.05	.....	24	1.10	1.20	.50	.10	.....
9	1.50	1.50	.40	.05	.....	25	1.10	1.00	.40	.10	.....
10	1.50	1.60	.40	.05	.....	26	1.00	1.00	.30	.05	.....
11	1.50	1.70	.30	.05	.....	27	1.00	1.00	.25	.05	.....
12	1.60	1.70	.30	.20	.....	28	1.00	.90	.30	.05	.....
13	1.50	1.70	.30	.30	.....	29	1.10	.....	.30	.05	.....
14	1.40	1.70	.20	.35	.....	30	1.10	.....	.35	.10	.....
15	1.40	1.60	.20	.35	.....	31	1.20	.....	.30	.....	.....
16	1.30	1.60	.20	.30	.....						

ARKANSAS RIVER NEAR ROCKYFORD, COLO.

The old station was located 2 miles northeast of Rockyford, Colo., and was established May 3, 1897. The gage consisted of a vertical 1 by 3 inch timber notched in tenths and securely nailed to the pile protection to the abutment of the wagon bridge at the left side of the stream, upper side of the bridge. The initial point for soundings was on the left bank at the water's edge. Both banks are high and liable to overflow only at very high water. The channel is straight for about 300 feet above and below the station. The bed is sandy and shifting. This station was abandoned April 7, 1900.

A new station was established by R. W. Hawley on April 19, 1901, at a point 3½ miles northwest from Rockyford station on the Atchison, Topeka and Santa Fe Railway. A steel cable was stretched across the river and supplied with a car, and an inclined timber gage rod was bolted into the shale on the north side of the river and marked. The bench mark consists of a cut in a tree at the initial point level with a 10-foot mark on the rod. The records were kept through the courtesy of the American Beet Sugar Company, Fred Chappell, agriculturist, taking the reading. The channel is fairly favorable for good results, being at what is known as the old ford. The bottom is of shale and usually free from sand, although filled in to a certain extent at some stages. Gagings may be made either by means of the cable and car or by wading. The point is of especial importance, owing to the fact that it is one of the few places on the Arkansas River where the channel is at all permanent.

Daily gage height, in feet, of Arkansas River near Rockyford, Colo.

Day.	Jan.	Feb.	Mar.	Day.	Jan.	Feb.	Mar.
1902.				1902.			
1	1.80	2.00	2.00	17	1.50	2.00	2.50
2	1.70	2.20	2.20	18	1.50	2.00	2.00
3	1.80	2.50	2.00	19	1.50	2.00	2.00
4	1.80	2.50	1.80	20	1.60	2.00	1.80
5	1.80	2.50	2.20	21	1.50	2.00	2.20
6	1.90	2.40	2.00	22	1.60	2.00	2.20
7	1.90	2.30	2.00	23	1.60	1.90	1.80
8	1.90	2.20	1.80	24	1.50	1.80	2.20
9	1.80	2.40	2.00	25	1.50	2.20	2.00
10	1.70	2.60	1.80	26	1.60	2.00	1.80
11	1.70	2.60	2.20	27	1.60	2.20	2.20
12	1.50	2.50	2.30	28	1.60	2.00	1.80
13	1.60	2.70	2.20	29	1.60	.....	1.80
14	1.50	2.40	2.00	30	1.90	.....	2.20
15	1.50	2.50	2.20	31	1.90	.....	2.00
16	1.50	2.00	2.50				

Rating table for Arkansas River near Rockyford, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet*	*Second-feet.*	*Feet.*	*Second-feet.*
−0.2	25	1.2	181	2.6	1,665	4.0	4,420
.0	32	1.4	238	2.8	2,035	4.2	4,820
.2	43	1.6	343	3.0	2,424	4.4	5,220
.4	56	1.8	510	3.2	2,820	4.6	5,620
.6	73	2.0	735	3.4	3,220	4.8	6,020
.8	101	2.2	1,009	3.6	3,620		
1.0	137	2.4	1,321	3.8	4,020		

Estimated monthly discharge of Arkansas River near Rockyford, Colo.

[Drainage area, 11,440 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	616	282	402	24,718	0.035	0.04
February	1,848	510	1,081	60,036	.094	.10
March	1,489	510	828	50,896	.072	.08

ARKANSAS RIVER NEAR NEPESTA, COLO.

The original station, established September 8, 1897, is located 1,(feet north of Nepesta, Colo., at a wagon bridge, 200 feet below t Atchison, Topeka and Santa Fe Railroad. The gage consists of vertical timber graduated to feet and tenths, securely fastened to upstream cylinder of the bridge, on the left side of the river. The ch nel above and below the station is straight for several hundred fe while the bed is sandy and shifting, and the results, therefore, are altogether satisfactory for the purpose of making a rating table. T station was maintained by the Great Plains Water Company u December, 1900. May 1, 1901, another station was established A. L. Fellows, assisted by C. W. Beach, at the dam and head gate the Oxford Farmers' Canal, 1½ miles west of Nepesta. The stat consists of the dam crossing the river at the head gate forming a w and a gage rod, consisting of a 2 by 6 inch timber, 8 feet long, faste to an oak pile at the south end of the dam; the location being marl by spikes driven into the pile at each foot mark. The rod is gradua to feet and tenths vertically. At low stages the stream may be me ured by wading, but at high stages it is necessary to use the wa bridge at Nepesta, making the necessary allowances for inflow betw the two points; this can readily be done, as the distance is only al a mile. The observer is Z. Swallow, head gate keeper of the Oxf Farmers' Canal. The station will prove of particular value, as i near the head of irrigation district No. 17, one of the most impor on the Arkansas River.

The table of the discharge of the Oxford Farmers' Canal has b furnished by their secretary, F. M. Weiland. Readings were ta only on those days when the river gage read zero.

During 1902 the following discharge measurements were made C. W. Beach:

May 23: Gage height, 0.50 feet; discharge, 234 second-feet.
June 28: Gage height, 0.60 feet; discharge, 127[a] second-feet.

Daily gage height, in feet, of Arkansas River near Nepesta, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	N
1902.								
1	0.58	.....	0.92	.....	.....	0.72	0.51	
2	.61	.....	.91	.....	.....	.59	.59	...
3	.61	0.27	.98	.....	.....	.53	.61	...
4	.55	.62	1.05	.....	.....	.51	.61	...
5	.54	.79	1.02	0.20	.....	.42	.59	...
6	.63	.80	.95	.20	1.75	.39	.51	...
7	.61	.67	.98	.59	1.55	.41	.50	...
8	.52	.75	.95	.57	.62	.39	.49	...

[a] Water fell 0.05 during gaging.

ly gage height, in feet, of Arkansas River near Nepesta, Colo.—Continued.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
.....	0.57	0.87	0.93	0.44	0.53	.....	0.50	.....
.....	.60	.80	.85	.72	.42	.....	.51	.....
.....	.59	.85	.85	1.42	.....	.....	.49	.....
.....	.55	1.20	.87	1.60	.52	.....	.51	.....
.....	.62	1.17	.83	.44	.50	.....	.50	.....
.....	.64	1.16	.87	.41	.61	0.39	.51	.....
.....	.59	1.22	.86	.39	.49	.....	.50	.....
.....	.51	1.16	.87	.19	.50	.....	.50	.....
.....	.49	1.21	.79	.60	.51	.....	.49	.....
.....	.49	1.19	.75	1.90	.39	.....	.52	.....
.....	.42	1.12	.69	1.30	.19	.....	.51	.....
.....	.48	1.02	.68	.50	.....	.....	.50	.....
.....	.22	.78	.64	.20	.....	.52	.50	.....
.....	.27	.65	.59	.....	.....	.59	.52	.....
.....	.36	.64	.61	.....	.20	.61	.52	.....
.....	.36	.72	.53	.....	.44	.56	.51	.....
.....	.....	.75	.56	.....	.51	.50	.50	.....
.....	.....	.73	.51	.....	1.10	.49	.52	.....
.....	.....	2.65	.51	.55	1.40	.48	.50	.....
.....	.17	2.65	1.25	.51	1.12	.49	.50	.....
.....	.17	1.72	1.73	.25	.75	.59	.50	.....
.....	.17	1.22	.25	.....	.59	.59	.50	.....
.....	.....	1.05	.....	.....	2.00	.....	.52	.....

Discharge of Oxford Farmers' Canal.

Date.	River gage.	Second-feet in Oxford Farmers' Canal.	Date.	River gage.	Second-feet in Oxford Farmers' Canal.
.....	0.00	75	August 11.....	0.00	80
.....	0.00	53	August 20.....	0.00	14
.....	0.00	14	August 21.....	0.00	14
.....	0.00	14	August 22.....	0.00	14
.....	0.00	14	September 9.....	0.00	30
.....	0.00	14	September 10.....	0.00	14
.....	0.00	14	September 11.....	0.00	14
.....	0.00	8	September 12.....	0.00	18
.....	0.00	6	September 13.....	0.00	20
.....	0.00	14	September 15.....	0.00	14
.....	0.00	14	September 16.....	0.00	14
1.....	0.00	6	September 17.....	0.00	14
2.....	0.00	6	September 18.....	0.00	14
3.....	0.00	6	September 19.....	0.00	14
4.....	0.00	14	September 20.....	0.00	14
5.....	0.00	14			

25, 26, and 27 gage rod read zero, but no flow in canal recorded.

Rating table for Arkansas River near Nepesta, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	21	1.6	2,067	3.0	5,202	4.4	8,400
.4	61	1.8	2,506	3.2	5,658	4.6	8,860
.6	200	2.0	2,949	3.4	6,114	4.8	9,324
.8	465	2.2	3,396	3.6	6,570	5.0	9,788
1.0	815	2.4	3,844	3.8	7,026		
1.2	1,217	2.6	4,296	4.0	7,482		
1.4	1,635	2.8	4,748	4.2	7,940		

Estimated monthly discharge of Arkansas River near Nepesta, Colo.[a]

[Drainage area 9,130 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	244	0	119	7,081	0.013	0.015
May	4,409	0	936	57,552	.103	.119
June	2,352	28	566	33,679	.062	.069
July	2,727	0	312	19,184	.034	.039
August	9,208	0	643	39,537	.070	.081
September	348	0	87	5,177	.010	.011
October	211	108	129	7,932	.013	.015

[a] These figures do not include the flow of Oxford Farmers' Canal.

ARKANSAS RIVER AT PUEBLO, COLO.

This station was established in September, 1894, by A. P. Davis. Originally there were two gage rods. The main gage was located at the Santa Fe Avenue Bridge and consisted of a vertical 6 by 6 inch timber, and a 1 by 6 inch scale bolted to the abutment of the Denver and Rio Grande Railroad bridge on the left-hand side of the river, graduated to tenths of a foot. There was also a short vertical rod for extreme low water spiked to a pile about 20 feet out in the stream, reading the same as the main gage. The 12-foot mark of this gage was opposite the top of the large capstone. The rod at Victoria Avenue Bridge consisted of inclined 4 by 4 inch timbers fastened to posts set in the right bank of the stream, graduated to vertical tenths of a foot, the space between the marks being 0.242 of a foot. This rod was placed in June, 1895, for the purpose of noting the change in the slope of the water surface. The rods were read until July 10, 1898, when on account of the shifting of the bed of the river they were abandoned and a new gage was installed on the east side of the Main Street Bridge. From this bridge all the discharge measurements were made until the season of 1902.

channel at this point is excellent, and it would be of very great o the entire division to have a permanent station of concrete shed here. The channel, which is of bowlders and gravel, is d by high masonry walls, so that there is little change, except fills during low water and scours out during high water. w of the stream is rapid, but not too swift for accurate meas- ts. This station is an important one, being located near the the principal irrigation portion of the valley, only one ditch of ance being taken out above it in the Pueblo district, although rable water is used in the ditches in the neighborhood of Can- hich is in another water district. It is upon the gagings made point that the water superintendents and commissioners depend ribution of water to ditches below.

ings were made at Main street bridge until March 3, 1900, when to the scouring of the channel it became necessary to replace ge by one about 60 feet below the south end of the Union bridge. This gage was a 2 by 6 inch vertical timber, bolted e former rod to the masonry wall and graduated to feet and On June 13, 1900, this rod was connected with a bench mark coping at the northwest corner of the Union avenue bridge, was found to be 19.79 feet above the zero of the rod. In 1902, another rod exactly similar to the one last mentioned was in a vertical position to the masonry wall on the right-hand f the river about 30 feet above the south end of the Union bridge. All gage heights up to July 14, 1902, were taken the rod just below the Union avenue bridge. After July 14, the readings were taken from the rod above the bridge, the ations on the former rod being too dim to be read at low water. erence of 0.2 of a foot existed between the two rods when the ne was set, the new rod reading 0.2 of a foot higher than the old In all the discharge measurements made during 1902 the gage was taken from the new rod above the Union avenue bridge. bserver during 1902 was T. J. Burrows, water commissioner of ieblo water district.

Discharge measurements of Arkansas River at Pueblo, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
5	J. E. Field	1.80	220
	C. W. Beach	3.30	1,323
	do	1.80	193
	J. E. Field	1.60	130
24	M. C. Hinderlider	2.20	358
ber 1	C. W. Beach	2.17	341
ber 21	do	2.05	212

Daily gage height, in feet, of Arkansas River at Pueblo, Colo.

Day.	Jan.	Feb.	Mar.	Apr	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.20	4.20	2.10	1.80	2.00	2.65	1.90	1.30	2.20	2.00	2.10	2.0
2	2.20	3.70	2.10	1.80	2.00	2.60	2.20	1.40	1.90	2.00	2.10	2.10
3	2.20	3.70	2.00	1.80	2.10	2.62	2.05	1.75	2.00	2.10	2.10	2.10
4	2.30	3.50	2.00	1.80	2.30	2.80	2.05	1.80	2.00	2.10	2.10	2.1
5	2.30	3.50	1.90	1.80	2.60	2.70	2.05	8.10	2.00	2.10	2.10	2.1
6	2.20	3.50	2.00	1.80	2.60	2.70	1.80	3.00	2.00	2.10	2.10	2.1
7	2.25	3.50	2.10	1.80	2.87	2.70	1.70	2.70	2.00	2.00	2.10	2.1
8	2.25	3.70	2.00	2.00	2.95	2.70	1.70	2.30	2.00	2.00	2.10	2.1
9	2.10	3.70	2.00	2.00	2.65	2.70	1.70	2.30	2.00	2.00	2.10	2.1
10	2.10	3.50	2.05	2.00	3.00	2.55	3.35	2.30	1.90	2.00	2.10	2.1
11	2.10	3.70	2.00	2.00	3.40	2.50	2.05	2.00	1.90	2.00	2.10	2.1
12	2.15	3.80	2.00	2.00	3.40	2.70	1.70	2.00	1.90	2.00	2.00	2.10
13	2.10	3.70	2.00	2.00	3.40	2.67	1.70	2.00	2.00	2.00	2.30	2.10
14	2.10	3.40	2.00	2.00	3.40	2.65	2.00	2.00	1.90	2.00	2.00	2.10
15	2.10	3.25	2.00	2.00	3.40	2.65	1.60	1.90	2.00	2.10	2.00	2.10
16	2.10	2.20	2.00	2.00	3.40	2.60	1.60	1.90	2.00	2.10	2.00	2.10
17	2.10	2.70	2.00	1.95	3.40	2.65	2.02	1.90	2.00	2.20	2.00	2.20
18	2.30	2.20	1.90	1.90	3.40	2.50	2.30	1.90	2.00	2.20	2.00	2.20
19	2.30	2.15	1.95	1.80	3.30	2.35	2.30	1.90	2.00	2.20	2.00	2.20
20	2.20	2.10	2.00	1.80	3.05	2.30	2.20	1.80	2.00	2.20	2.00	2.10
21	2.10	2.10	2.00	1.80	2.85	2.40	2.30	1.80	2.25	2.20	2.20	2.10
22	2.05	2.10	2.00	2.00	2.60	2.30	2.10	2.35	2.15	2.20	2.20	2.20
23	2.00	1.95	2.00	2.00	2.40	2.20	2.10	2.25	2.10	2.20	2.10	2.20
24	2.10	1.80	2.00	1.90	2.30	2.20	2.00	2.30	2.10	2.20	2.10	2.20
25	2.10	1.70	2.00	1.80	2.20	2.10	1.85	2.10	2.10	2.20	2.20	2.20
26	2.15	2.10	1.90	1.90	2.40	2.00	1.80	2.30	2.10	2.20	2.15	2.20
27	2.15	2.10	1.90	2.10	2.75	1.90	1.70	3.45	1.90	2.10	2.10	2.20
28	2.20	2.10	1.90	2.00	3.20	2.20	2.20	2.10	1.90	2.10	2.10	2.20
29	2.20	.....	1.90	2.00	2.75	2.35	1.60	1.90	2.00	2.10	2.10	2.20
30	2.20	.....	1.90	2.00	2.70	2.00	1.50	2.00	2.00	2.10	2.10	2.20
31	2.20	.....	1.80	.....	2.70	.....	1.30	2.25	.....	2.10	.....	2.20

Rating table for Arkansas River at Pueblo, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	20	3.0	985	5.0	3,523	7.0	6,538
1.2	43	3.2	1,205	5.2	3,811	7.2	6,855
1.4	80	3.4	1,443	5.4	4,103	7.4	4,176
1.6	129	3.6	1,687	5.6	4,398	7.6	7,501
1.8	190	3.8	1,931	5.8	4,696	7.8	7,829
2.0	265	4.0	2,175	6.0	4,996	8.0	8,157
2.2	360	4.2	2,425	6.2	5,300	8.2	8,485
2.4	481	4.4	2,685	6.4	5,605	8.4	8,813
2.6	625	4.6	2,957	6.6	5,913		
2.8	791	4.8	3,238	6.8	6,224		

Estimated monthly discharge of Arkansas River at Pueblo, Colo.

[Drainage area, 4,600 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	417	265	343	21,090	0.075	0.086
February	2,425	158	1,070	59,425	.231	.241
March	310	190	258	15,863	.056	.065
April	310	190	234	13,924	.051	.057
May	1,443	265	876	53,863	.190	.219
June	791	225	543	32,311	.116	.129
July	1,382	60	277	17,032	.060	.069
August	8,321	60	613	37,692	.133	.153
September	360	225	271	16,126	.059	.066
October	360	265	311	19,123	.068	.078
November	417	265	307	18,268	.067	.075
December	360	287	333	20,475	.072	.083
The year	8,321	60	453	325,192	.098	1.321

ARKANSAS RIVER NEAR CANYON, COLO.

This station is located at the Hot Springs Hotel, 1½ miles west of Canyon and a short distance below the mouth of Grape Creek. Observations at this point were begun on April 17, 1889, the station being established here by Robert Robertson. The record has been maintained since that time, with occasional breaks due to absence or change of observer. The station is of special importance, being located at the mouth of the canyon and at a point practically above all of the irrigation ditches, except the Canyon City ditch (sometimes called the North Side ditch) and the South Canyon ditch (sometimes called the South Side ditch), both of which head above the station. During the irrigation season each of these ditches carries from 25 to 60 cubic feet of water per second, according to the needs of the irrigators, and their discharge should be added to the discharge at the station in order to obtain the total run-off at the mouth of the canyon. This site was used in 1888 for a gaging station by the State engineer of Colorado, and is highly favorable for obtaining accurate measurement. The channel of the river is straight for several hundred yards, both above and below, and the current, though swift, is not too great at high water nor too sluggish at low stages for satisfactory results. The banks on both sides are high and are not overflowed. The cross

section is regular and has not been subject to notable changes, except on the right bank, near the gage, where a sand bar has formed at times of low water.

The gage rod established by Mr. Robertson was of 2 by 6 inch timber, inclined, and attached to the crib of an old bridge on the south or right-hand side of the river, almost directly in front of the hotel. There were two bench marks: No. 1, on the top of a log of the crib; elevation, 10.01 feet above the datum; No. 2, in the cleft of a red bowlder at the foot of a charred stump 50 feet downstream and on the same side of the river; elevation, 9.60 feet. On April 13, 1891, the station was inspected by Frank Tweedy, and a third bench mark was established, this being a bedded rock 40 feet from the north end of the cable, toward Hot Springs Hotel and 10 feet from the river bank. It is marked "B. M. No. 3, U. S. G. S.," and is 15.98 feet above the zero of the gage. The present observer is Dr. J. L. Prentiss.

The measurements were at first made from a car suspended from a cable stretched across the river, the bridge from which measurements were originally made by the State engineer having been destroyed. Later a new suspension bridge was constructed in front of the hotel, necessitating the removal and replacement of the gage, and subsequent measurements were made from this bridge, which, having a clear span, offers no obstruction to the current. On October 4, 1895, it was found that the top of the gage had been broken off, necessitating its renewal for readings during high water. The channel was found to be filled with sand and gravel in front of the gage, requiring considerable work in order to make the water flow to the rod. It was decided, therefore, to put in a new gage where the stream could not deposit material. A point was chosen about 100 feet below the bridge, on the left bank, and a crib was built, anchored in place by rocks and bolts, the lower end of the gage being fastened to it. The upper end of the inclined portion was attached to a juniper tree. On December 27, 1895, the station was inspected, and it was found that readings had been made from the old rod, which, at the stage of water prevailing, recorded about 0.40 of a foot above the new rod on the opposite side of the river. When the water is high and extends with unbroken surface from bank to bank the readings are the same, but at low water the observations on the old rod are misleading, owing to the accumulation of sand and gravel in front of it.

On August 26, 1902, owing to the shifting of the channel a new rod, consisting of 4 by 4-inch timber, was placed in an inclined position on the north or left bank of the river at the site of the previous rod just below the north end of the suspension bridge. The rod on this date read practically the same as the old rod. The bench mark is the top point of a granite boulder embedded in the earth 60 feet east of the south end of the bridge, and about 10 feet from the south bank of the river. The zero of the rod is 16.055 feet below the bench mark.

The following discharge measurements were made during 1902 by J. E. Field and M. C. Hinderlider:

April 21: Gage height, 2.20 feet; discharge, 323 second-feet.
July 26: Gage height, 1.60 feet; discharge, 165 second-feet.
August 26: Gage height, 2.00 feet; discharge, 226 second-feet.

Daily gage height, in feet, of Arkansas River near Canyon, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.30	2.20	2.30	2.40	2.35	3.05	2.30	1.58	2.20	2.10	2.30	2.30
2	2.30	2.30	2.30	2.40	2.40	3.00	2.30	1.90	2.15	2.20	2.25	2.40
3	2.30	2.30	2.30	2.40	2.50	2.95	2.30	1.90	2.05	2.20	2.20	2.40
4	2.30	2.30	2.30	2.40	2.60	2.90	2.10	2.00	2.00	2.20	2.20	2.40
5	2.20	2.30	2.30	2.50	2.75	2.90	1.88	2.40	2.00	2.25	2.20	2.30
6	2.20	2.30	2.30	2.45	2.90	2.90	1.80	2.75	2.00	2.30	2.20	2.30
7	2.20	2.30	2.30	2.40	3.00	2.85	2.05	2.05	2.00	2.20	2.20	2.30
8	2.20	2.30	2.30	2.30	3.15	2.75	2.00	1.78	1.95	2.20	2.10	2.30
9	2.20	2.30	2.30	2.20	3.25	2.90	2.25	1.70	1.90	2.20	2.10	2.30
10	2.20	2.30	2.30	2.20	3.50	2.90	1.88	1.62	1.90	2.20	2.10	2.30
11	2.20	2.30	2.30	2.10	3.60	2.90	1.80	1.60	1.90	2.25	2.10	2.20
12	2.30	2.30	2.30	2.10	3.75	2.90	1.72	1.70	1.90	2.25	2.10	2.20
13	2.30	2.30	2.30	2.00	3.70	2.80	1.68	1.65	1.90	2.20	2.10	2.20
14	2.30	2.30	2.30	2.00	3.70	2.80	1.62	1.70	1.90	2.20	2.20	2.35
15	2.30	2.30	2.30	2.00	3.60	2.80	1.60	1.75	1.90	2.20	2.20	2.40
16	2.30	2.30	2.30	2.00	3.75	2.80	1.58	1.80	1.90	2.30	2.20	2.45
17	2.30	2.30	2.30	1.95	3.55	2.70	1.85	1.80	1.90	2.35	2.30	2.50
18	2.30	2.30	2.30	1.88	3.50	2.70	1.90	1.80	1.90	2.30	2.30	2.40
19	2.20	2.30	2.30	1.95	3.40	2.60	1.85	1.80	1.90	2.30	2.20	2.35
20	2.20	2.30	2.30	2.10	3.20	2.55	2.40	1.80	1.90	2.30	2.20	2.30
21	2.20	2.30	2.30	2.10	2.90	2.50	2.40	2.35	2.10	2.30	2.20	2.30
22	2.20	2.30	2.30	2.15	2.70	2.35	2.25	2.45	2.20	2.30	2.30	2.40
23	2.20	2.30	2.40	2.10	2.65	2.20	2.25	2.00	2.20	2.30	2.35	2.40
24	2.20	2.30	2.40	2.00	2.55	2.05	1.95	1.90	2.15	2.20	2.30	2.50
25	2.20	2.30	2.40	2.00	2.50	2.10	1.65	1.95	2.15	2.20	2.20	2.50
26	2.20	2.30	2.40	2.00	2.60	2.35	1.55	2.30	2.10	2.20	2.20	2.45
27	2.20	2.30	2.40	2.10	3.15	2.50	1.58	3.00	2.05	2.20	2.20	2.40
28	2.20	2.30	2.40	2.10	3.35	2.50	1.50	2.65	2.00	2.30	2.20	2.35
29	2.20	.....	2.40	2.20	3.00	2.45	1.42	2.40	2.00	2.25	2.20	2.20
30	2.20	.....	2.40	2.25	3.00	2.40	1.40	2.35	2.05	2.20	2.30	2.10
31	2.20	.....	2.40	.....	3.00	.....	1.40	2.25	.....	2.20	.....	2.15

Rating table for Arkansas River near Canyon, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	62	1.7	185	2.4	360	3.1	716
1.1	78	1.8	206	2.5	393	3.2	791
1.2	94	1.9	228	2.6	432	3.3	872
1.3	110	2.0	252	2.7	476	3.4	957
1.4	128	2.1	277	2.8	527	3.5	1,046
1.5	146	2.2	303	2.9	584	3.6	1,139
1.6	165	2.3	331	3.0	647	3.7	1,236

Estimated monthly discharge of Arkansas River near Canyon, Colo.

[Drainage area, 3,060 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	331	303	317	19,492	0.104	0.12
February	331	303	325	18,050	.106	.11
March	360	331	337	20,721	.110	.13
April	393	228	294	17,494	.096	.11
May	1,286	345	757	46,546	.250	.29
June	681	264	481	28,622	.157	.18
July	360	128	229	14,081	.075	.09
August	647	161	270	16,602	.090	.10
September	303	228	254	15,114	.083	.09
October	345	277	313	19,246	.102	.12
November	345	277	294	17,494	.100	.11
December	393	277	342	21,029	.112	.13
The year	1,286	128	351	254,491	.115	1.58

ARKANSAS RIVER AT SALIDA, COLO.

This station is located at the footbridge near the railroad shops at Salida, Colo. It was originally established by the Denver and Rio Grande Railroad April 11, 1895. The original gage rod was a vertical timber fastened to the north side of the footbridge. Considerable difficulty was experienced by its being knocked out by ice and by logs during high water, and a new inclined gage rod was put in place during the spring of 1901 by J. E. Field, consisting of a 6 by 6 inch oak timber fastened to the north trestle of the bridge, the graduations being extended by marks on the trestle above the timber. On July 31, 1901, the gage was lowered and set farther out into the stream.

Another gage was established at this station on August 27, 1902, the zero of which is 1.10 feet below the zero of the old gage. The gage heights from this date are taken on the new rod.

The measurements are all made from the suspension footbridge back of the Denver and Rio Grande Railroad.

The banks are high and do not overflow. The bed of the stream consists of sand, gravel, and boulders. Two large boulders interfere to a great extent with the accuracy of the results. As the station is an important one, these boulders should be removed, so as to improve the character of the channel, and thus render the results of measurements more reliable. The stream is very swift at this point, but the channel is straight, and the discharge can readily be measured from

the footbridge. Little water is used above Salida, and none is used below that place until Canyon is reached. The observer is William Furniss. The gage heights have been sent to the local forecast official of the Weather Bureau at Denver, who has had them published in the morning papers.

Discharge measurements of Arkansas River at Salida, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 11	J. E. Field	0.55	273
April 12	do	.55	286
May 5	do	1.40	706
May 19	do	1.80	1,144
May 12	M. C. Hinderlider	2.20	1,804
July 26	do	.30	224

Daily gage height, in feet, of Arkansas River at Salida, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
1	0.10	0.75	1.45	0.80	0.20	1.20	1.10
2	.10	.85	1.50	.70	.25	1.30	1.10
3	.10	.95	1.35	.55	.30	1.20	1.20
4	.10	1.10	1.30	.45	.30	1.05	1.20
5	.15	1.10	1.30	.40	.35	1.00	1.20
6	.25	1.30	1.30	.35	.40	1.00	1.20
7	.30	1.55	1.30	.30	.40	1.00	1.20
8	.30	1.60	1.30	.30	.30	1.00	1.20
9	.30	1.60	1.20	.25	.20	1.00	1.20
10	.25	1.70	1.20	.20	.20	1.00	1.20
11	.20	1.80	1.20	.20	.20	1.00	1.20
12	.20	1.85	1.20	.20	.20	1.00	1.20
13	.20	2.00	1.10	.20	.20	1.00	1.15
14	.20	2.05	1.10	.20	.10	1.00	1.10
15	.20	2.10	1.05	.20	.10	1.00	1.10
16	.10	2.10	1.00	.15	.10	1.00	1.00
17	.10	2.00	1.00	.10	.10	.90	1.00
18	.10	2.00	.90	.10	.10	.85	.95
19	.20	1.75	.75	.50	.15	.80	1.00
20	.35	1.55	.70	.60	.40	.80	1.05
21	.45	1.15	.70	.55	.60	.80	1.00
22	.35	.95	.65	.50	.55	1.15	1.00
23	.30	.90	.60	.40	.35	1.25	1.05
24	.30	.90	.55	.30	.30	1.20	1.10
25	.30	.95	.50	.25	.30	1.15	1.10
26	.35	1.20	.50	.15	.30	1.10	1.10
27	.45	1.50	.70	.10	[a] 1.30	1.05	1.05
28	.50	1.45	.70	.10	1.25	1.10	1.00
29	.50	1.45	.80	.10	1.20	1.10	.90
30	.60	1.60	.80	.10	1.20	1.10	.90
31	.....	1.40	.....	.20	1.20	.....	.90

[a] New rod placed on this date. Old rod read 0.2 foot; new rod read 1.30 feet. The heights from this time on are read from the new rod.

Rating table for Arkansas River at Salida, Colo., for 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
—0.3	140	.5	268	1.3	622	2.1	1,615
— .2	150	.6	293	1.4	702	2.2	1,799
— .1	162	.7	320	1.5	798	2.3	1,991
.0	175	.8	353	1.6	906	2.4	2,188
.1	190	.9	393	1.7	1,024	2.5	2,388
.2	206	1.0	441	1.8	1,150		
.3	224	1.1	494	1.9	1,287		
.4	245	1.2	554	2.0	1,442		

[a] This table is referred to the old gage. In using it 1.10 feet were subtracted from all gage heights after August 26.

Estimated monthly discharge of Arkansas River at Salida, Colo.

[Drainage area, 1,160 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	293	190	219	13,031	0.19	0.21
May	1,615	336	852	52,387	.73	.84
June	798	268	467	27,788	.40	.45
July	353	190	229	14,081	.20	.23
August	293	190	217	13,343	.19	.22
September	206	140	168	9,997	.14	.16
October	190	150	174	10,699	.15	.17

Miscellaneous measurements in the Arkansas River drainage basin for 1902.

[Made by W. P. Edwards.]

Date.	Stream.	Locality.	Discharge.
			Second-feet.
July 11	Trout Creek	Newell	4
July 12	Chalk Creek	Mount Princeton	17

RED RIVER DRAINAGE BASIN.

The headwaters of the Red River include several forks, all of which have their sources in northern Texas. Red River takes a general easterly direction along the northern boundary of Texas, and then turns toward the southeast and flows through a low, swampy region in Louisiana into the Mississippi, not far from the southern boundary of Mississippi. The Washita River rises in northern Texas, crosses southern Oklakoma, and flows into the Red River in the southern part of Indian Territory, about 10 miles from Denison, Tex.

The Sulphur Fork of the Red River has its headwaters in Hunt and Fannin counties, flows eastward, forming the boundary between Delta, Red River, and Bowie counties on the north, and Hopkins, Franklin, Titus, Morris, and Cass counties on the south, and empties into the Red River in Arkansas about 7 miles north of the boundary line between that State and Louisiana. The flow of this river is very unreliable, changing with the rainfall. If the summer is at all dry it ceases to flow altogether, but there always remains enough water standing in pools to water stock. During or immediately after protracted or unusually heavy rains, the river becomes very wide and deep, floods its bottoms, and often occasions considerable loss of stock and damage to planters and the railroads.

The Big Cypress River has its headwaters in Franklin and Titus counties, flows in a generally easterly direction, and empties into the Red River. The flow of the river is unreliable, varying with the rainfall. In the summer it ceases to flow, becoming dry, except in those places where the water stands in holes. After long or heavy rains the stream is liable to overflow its banks.

The Washita River at Anadarko is the only regular station in the Red River drainage basin.

WASHITA RIVER AT ANADARKO, OKLA.

This station, established October 25, 1902, by W. G. Russell, is located at the highway bridge, one-half mile north of the Anadarko railroad depot. The gage is of the usual wire type, with the scale-board graduated to feet and tenths, and spiked to the hand rail of the bridge. The initial point for sounding is on the right bank. The channel both above and below the station is straight for 200 feet; the right bank is high, and the left bank is low; both banks are liable to overflow; the bed of the stream is sandy and constant. The observer is James H. Dunlap, who reads the gage once each day.

The following discharge measurement was made in 1902:

October 25: Gage height, 2.50 feet; discharge, 171 second-feet.

Daily gage height, in feet, of Washita River at Anadarko, Okla.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.			
1		2.50	4.00	17		2.60	7.20
2		2.70	3.80	18		2.60	6.10
3		2.70	3.70	19		2.60	4.30
4		4.30	3.60	20		2.60	3.90
5		4.85	3.50	21		2.70	3.70
6		4.50	3.40	22		2.80	3.60
7		3.50	3.40	23		7.40	3.50
8		3.20	3.30	24		9.20	3.40
9		3.00	3.20	25		7.60	3.30
10		2.80	3.20	26	2.50	6.70	3.20
11		2.70	3.20	27	2.50	5.40	3.10
12		2.70	3.10	28	2.50	4.80	3.10
13		2.70	3.10	29	2.50	4.60	3.10
14		2.70	3.10	30	2.50	4.20	3.10
15		2.70	3.30	31	2.50		3.10
16		2.60	5.60				

Miscellaneous measurements in the Red River drainage basin.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
December 23	Sulphur Fork	St. Louis Southwestern Railroad bridge, near Naples, Tex.	[a] 3,097
December 24	Big Cypress	St. Louis Southwestern Railroad bridge, near Pittsburg, Tex.	[b] 101
November 17	Ouachita	Camden, Ark	2,477
November 15	Red	Garland, Ark	18,627

[a] Water 6 feet (approximately) above normal winter level.
[b] Water 2 feet (approximately) above normal winter level.

WESTERN GULF DRAINAGE.

Those stations from which the United States Geological Survey has obtained data during 1902, and which are located on rivers which drain into that portion of the Gulf of Mexico west of the Mississippi River, have been grouped into the following drainage basins: Sabine, Neches, Trinity, Brazos, Colorado (of Texas), Guadalupe, and Rio Grande.

SABINE RIVER DRAINAGE BASIN.

The Sabine River has its headwaters in Collin and Hunt counties, flows in a southeasterly direction to the State line, then south, forming the boundary between Texas and Louisiana, and empties into Sabine Lake, an arm of the Gulf, near Orange, Tex. When measured on

December 25, 1902, the river was swollen by the rains of the previous two months. At the time the measurement was taken the river was 150 feet wide and had a maximum depth of 19 feet, which was said, by those residing near by, to be about 3 feet above normal. The banks are steep and the river is deep in the whole cross section. The drainage area of the Sabine above Orange, Tex., is 10,400 square miles. The principal tributary of the Sabine is the Big Sandy River, which rises in the northern part of Wood County, flows southeast through Wood and Upshur counties, and empties into the Sabine River near the town of Big Sandy. The stream has a reliable flow throughout the entire year. Its flow as measured December 25, 1902, was considerably in excess of the least flow of the stream, because there had been a protracted rainy period before the measurement was taken. There were at one time three mills on this stream, all of which are now abandoned or destroyed. The Seagore mill was situated about 100 yards below the crossing of the county road where the measurement was made. A dam, made by driving piling and filling in with stone, was used to store the water and give a greater fall. The fall obtained was 6 feet. The plant fell into decay and was finally washed away by floods. Almost all traces of the mill are now gone. Three miles farther upstream is the Silas Smith mill site, and still farther upstream the Kay mill site. Each of these mills has shared the same fate.

Miscellaneous measurements in the Sabine drainage basin.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
December 25	Sabine River	At St. Louis Southwestern Railroad crossing.	1,150
Do	Big Sandy River	At county road crossing, 2 miles northeast of Big Sandy.	188

NECHES RIVER DRAINAGE BASIN.

The Neches River rises in Van Zandt County and flows through the heavily wooded section of east Texas and finally empties into Sabine Lake near Beaumont. Its drainage area above Beaumont is 10,200 square miles. Its largest tributary is the Angelina, but it receives many smaller streams in its course, and on account of its flowing through a timbered section the flow of these tributaries, although small, is reliable, and many of them support small water-power plants. These plants are located in Van Zandt, Henderson, Angelina, San Augustine, Houston, and Tyler counties and are to be taken up and described later in a special report by T. U. Taylor on "The Water

Power and Water Supply of Texas." When measured on September 10, 1902, the water was what is termed in east Texas clear water, but it had the leaf-stain color and gave a chromine color to white objects beneath the surface. Near Grapeland, in Houston County, the San Pedro has its head and almost at its inception has sufficient water to support the water-power plant of Ferguson & Weisinger, where a 12-foot overshot wheel operates a gristmill and cotton gin of 50 saws.

In its lower sections the Neches becomes more sluggish in its flow, has deep water, and partakes of the bayou characteristics nearer the Gulf. Near Beaumont the water from Lake Sabine sometimes impregnates it with salt water.

The principal tributary of the Neches is the Angelina, which rises in Smith County, flows in a southeastwardly direction, and empties into the Neches near Townbluff. It was measured December 27, 1902, after protracted rains, at the crossing of the Houston East and West Texas Railroad, about 9 miles north of Lufkin, Tex., by Edward C. H. Bantel. The flow at that time was considerably above the average. This is considered a reliable stream, and is said to never go dry at this point. It is subject to floods which inundate extensive bottom lands, and cause considerable damage.

Miscellaneous measurements in the Neches drainage.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-fet.*
September 10	Neches	International and Great Northern Railroad bridge.	26
December 27	Angelina	North of Lufkin	1,361

TRINITY RIVER DRAINAGE BASIN.

The Trinity River rises in a network of small streams in the counties of Montague, Wise, and Parker, but their combined capacity at Dallas is not sufficient to keep the bottom or bed of the stream moist. The United States Geological Survey maintained a station at Dallas for a time, but it was abandoned on account of the small discharge. Below Dallas the Trinity flows through a wooded country, and consequently it is not subject to the sudden floods with their quick run-offs.

TRINITY RIVER AT RIVERSIDE, TEX.

The drainage area of the Trinity River above Riverside, Tex., is 16,000 square miles. A gaging station was established on the Trinity at Riverside, Tex., in December, 1902, by T. U. Taylor. The zero

of the gage is 66 feet below the top of the ties (or base of rail) in the north arm of the draw span of the International and Great Northern Railroad bridge. The elevation of the top of the pivot pier above gage datum is 56.5 feet, and that of the top of the channel of the lower chord of the arms of the draw span of the bridge is 62.9 feet. The gage consists of a tagged plumbers' chain to which is attached a lead weight in the form of a frustum of a cone. The bottom of the lead weight is marked 66, and every foot above this is marked with a brass tag giving its distance in feet above the bottom of the weight. The observer at Riverside is G. W. Higdon, who is in charge of the pumping plant of the International and Great Northern Railroad. In reading the gage it is only necessary to let the lead weight touch the water and then read off the distance the mark or point is from the upper end or zero mark of the chain.

The following measurements were made during 1902 on the Trinity and its tributaries:

September 10: At Riverside, gage height, 6 feet; discharge, 160 second-feet.
September 11: Near Oakwood, discharge, 120 second-feet.
September 11: Elkhart River, 4 miles northwest of Grapeland; discharge, 4 second-feet.

BRAZOS RIVER DRAINAGE BASIN.

This river has its source in the Staked Plains region of western Texas, and has a general southeasterly course, emptying into the Gulf of Mexico south of the mouth of Trinity River. Its drainage basin is entirely within the State of Texas.

Under the direction of Thomas U. Taylor the United States Geological Survey is maintaining stations in this basin at Waco and Richmond, Tex.

BRAZOS RIVER AT WACO, TEX.

On September 14, 1898, a gage was established on the southwest bank of Brazos River at Waco. It consists of an inclined iron bar, 3 inches by 1 inch, reading from 0 to 4.3 feet, bolted to a hard-pine stick 16 feet long, embedded in cement in the sloping limestone of the bank, flush with the surface, on which are painted the graduations above 4.3 feet. The gage is inclined to the horizontal at an angle whose sine is $\frac{5}{27}$. Three bench marks have been established. The first is on the lowest water table on the southwest pier of the suspension bridge, and is marked "U. S. G. S. 44.33 B. M." The hydrant at the corner of First and Austin streets is at an elevation (by gage) of 43.32 feet, while the top of the rail of the San Antonio and Aransas Pass Railroad a few feet from the hydrant is at an elevation of 41.12 feet. The bed of the river is shifting sand, and nearly every freshet modifies the cross section, so that at the same gage heights the river

sometimes flows in one and sometimes in two channels under the suspension bridge from which the measurements are made.

At high water the gage reading is obtained by measuring to the water surface from the top rail of the stiffening truss of the suspension bridge at a certain point when there is no load upon the bridge, and by taking this distance from 47.8 feet.

In the early part of 1902 a new camel-back truss bridge of one span was erected across the Brazos at Waco a few hundred feet above the suspension bridge. This new bridge crosses the river at an angle of 76 degrees. It has a footway on the east or downstream side that affords excellent facilities for measuring the flow of the stream, and there are no midstream piers to render measurements troublesome or doubtful. On the north pier of the new bridge a gage has been marked off to agree with the United States Geological Survey gage at the suspension bridge. The top of the cement floor of the new bridge at the southeast batter brace is at an elevation of 45.4 feet with respect to the United States Geological Survey gage. High-water gage heights can be read directly from the gage on the north pier, or the distance of the water surface can be measured from the cement floor and this subtracted from 45.4 feet will give the height of the river referred to the gage.

The Brazos reached in 1902 the lowest stage in its recorded history. In the latter part of 1901, from December 28 to 31, the gage reached the low mark of 2.3 feet, and several measurements were taken at this stage of the river to determine what was thought at that time to be the least discharge of the Brazos. An average discharge of 70 second-feet was then found. The river stood for seven days in January at this height and then fell to 2.2 feet, and then, in the latter part of January, it fell to 2.1 feet. During the first part of February the gage stood at 2.2 feet, but on the 19th of February again dropped to 2.1 feet. It remained at this height until March 7, when it dropped to 2 feet, the lowest mark since 1898, and the lowest mark ever reached on the gage. On March 8, 1902, the flow was measured by Thomas U. Taylor at a point 200 yards above the new bridge, at a section where the stream is only 24 feet wide. The average depth was 7 inches, and there was a mean velocity of 1.36 feet per second. This gave a discharge of 19 second-feet. This stage of the river continued until the afternoon of March 11.

Discharge measurements of Brazos River at Waco, Tex.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 14	C. N. Campbell	2.29	56
January 22	do	2.18	47
March 8	T. U. Taylor	1.98	20
July 25	do	21.00	70,500
July 30	do	16.00	26,700
July 31	do	14.00	20,800
August 1	do	11.80	13,800
August 5	do	6.70	4,200
September 5	do	4.90	1,730
September 6	do	4.30	1,230
December 17	do	3.71	892
December 20	do	3.68	863

Daily gage height, in feet, of Brazos River at Waco, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.30	2.20	2.10	4.60	2.75	5.90	4.40	11.65	3.20	4.85	2.55	5.80
2	2.30	2.20	2.10	4.60	2.70	7.00	4.15	9.25	3.15	5.55	2.50	7.65
3	2.30	2.20	2.10	4.20	2.60	8.60	3.70	8.25	3.10	6.10	3.55	6.45
4	2.30	2.20	2.10	3.90	2.60	7.50	3.50	7.20	4.40	6.10	3.70	6.20
5	2.30	2.20	2.10	3.60	2.80	8.75	4.05	6.70	4.55	6.90	3.30	6.20
6	2.30	2.20	2.10	3.40	3.00	7.40	5.30	6.40	4.40	5.85	8.80	5.60
7	2.30	2.20	2.05	3.85	3.20	6.20	5.50	6.20	5.55	5.20	7.60	5.00
8	2.20	2.20	2.00	3.50	3.40	5.75	4.75	5.75	5.20	4.80	7.10	4.80
9	2.20	2.20	2.00	4.60	4.90	5.30	4.30	5.35	4.60	4.75	5.90	4.75
10	2.20	2.20	2.00	4.40	7.50	4.95	3.95	5.05	6.70	4.50	5.70	4.65
11	2.20	2.30	2.20	4.00	6.95	4.55	3.50	4.85	7.20	4.30	5.30	4.50
12	2.20	2.30	3.70	3.85	5.95	4.45	3.40	4.65	6.00	00	5.30	4.40
13	2.20	2.30	3.75	5.25	5.45	4.35	3.75	4.50	5.35	3.75	5.35	4.40
14	2.20	2.20	3.20	4.90	5.15	4.10	3.80	4.40	5.10	3.60	7.70	4.35
15	2.20	2.20	4.80	3.90	5.65	3.85	5.10	4.40	4.90	3.40	5.70	4.30
16	2.20	2.20	7.00	3.65	5.75	3.70	5.10	4.30	4.75	3.30	7.80	3.80
17	2.20	2.20	5.80	5.00	4.90	3.90	5.90	4.20	4.55	3.20	10.30	3.65
18	2.10	2.20	5.35	4.60	4.40	4.10	4.65	3.85	4.30	3.10	8.80	3.70
19	2.10	2.15	5.20	4.10	8.95	3.70	4.60	3.70	4.00	3.10	5.95	3.70
20	2.10	2.10	5.10	3.90	12.15	3.50	4.60	4.30	3.85	3.00	5.80	3.60
21	2.10	2.10	5.05	3.60	7.75	3.35	4.75	4.05	3.75	3.10	9.35	3.60
22	2.20	2.10	4.50	4.15	7.25	3.30	7.05	3.75	3.70	3.85	7.05	3.50
23	2.20	2.10	4.45	3.90	8.50	3.30	11.40	3.70	3.65	3.45	6.70	3.50
24	2.20	2.10	3.95	3.65	10.80	3.40	11.60	3.70	3.45	3.60	6.40	3.50
25	2.10	2.10	3.80	3.50	10.45	3.15	15.50	3.60	3.40	3.60	14.75	3.50
26	2.20	2.10	3.55	3.40	9.75	3.10	32.10	3.55	3.35	3.50	8.65	3.50
27	2.20	2.10	3.45	4.25	8.35	4.90	31.35	3.35	3.45	3.15	6.80	3.50
28	2.20	2.10	3.80	3.40	8.05	5.10	27.05	3.30	6.15	3.05	6.20	3.50
29	2.20	.....	3.70	3.15	8.20	4.80	22.65	3.20	5.60	3.00	6.15	3.40
30	2.20	.....	5.00	3.10	7.70	4.80	17.30	3.20	5.05	3.00	6.05	3.40
31	2.20	.....	4.60	.....	6.90	.....	13.80	.....	.....	2.85	.....	3.40

Rating table for Brazos River at Waco, Tex., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.0	20	4.6	1,490	7.2	4,800	11.0	12,285
2.2	80	4.8	1,650	7.4	5,135	11.5	13,450
2.4	160	5.0	1,820	7.6	5,475	12.0	14,660
2.6	250	5.2	2,010	7.8	5,825	12.5	15,980
2.8	350	5.4	2,220	8.0	6,180	13.0	17,400
3.0	450	5.6	2,450	8.2	6,540	13.5	18,850
3.2	550	5.8	2,700	8.4	6,910	14.0	20,300
3.4	670	6.0	2,975	8.6	7,285	14.5	21,800
3.6	795	6.2	3,265	8.8	7,665	15.0	23,300
3.8	925	6.4	3,555	9.0	8,055	15.5	24,800
4.0	1,055	6.6	3,855	9.5	9,050	16.0	26,300
4.2	1,195	6.8	4,155	10.0	10,085	16.5	27,800
4.4	1,340	7.0	4,470	10.5	11,160	17.0	29,300

Estimated monthly discharge of Brazos River at Waco, Tex.

[Drainage area, 30,750 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
January	120	50	84	5,165	0.0027	0.003
February	120	50	74	4,110	.0024	.003
March	4,470	20	995	61,180	.0324	.037
April	2,062	500	1,062	63,193	.0345	.038
May	15,032	250	4,280	263,167	.1392	.160
June	7,570	500	2,123	126,327	.0690	.077
July	74,600	670	12,528	770,317	.4074	.470
August	13,810	550	2,354	144,742	.0766	.088
September	4,800	500	1,609	95,742	.0523	.058
October	4,310	375	1,230	75,630	.0400	.046
November	22,550	200	4,491	267,233	.1460	.163
December	5,562	670	1,494	91,862	.0486	.056
The year	74,600	20	2,694	1,968,668	.0876	1.199

BRAZOS RIVER AT RICHMOND, TEX.

The drainage area of the Brazos River above Richmond, Tex., is 44,000 square miles.

In the latter part of December, 1902, T. U. Taylor established a gaging station at Richmond, Tex., on the Brazos River. The gage consists of a tagged plumber's chain marked every foot with brass tags. The chain is 50 feet long, the bottom of the lead weight being the 50-foot mark. The zero of the gage is 50 feet below the top of the guard rail in the mid-span of the bridge of the Southern Pacific Railroad. The observer is W. B. Ransom, a local druggist, and observations were commenced on January 1, 1903.

Above and at Waco the river rises rapidly, and when it gets above the gage height of 30 feet overflows the bottom lands below the town. When the floods spread out over the bottom lands as they do from Waco to Richmond, the river stays up longer in its lower stretches than it does in the upper sections, as the the backwater in the bottoms and the lowlands serve as storage reservoirs and are drained slowly as the river recedes. At Hearne and below the river in 1899 was several miles in width. Its maximum height at Richmond occurred on July 7, 1899, when it stood 4 feet below the top of the guard rail, or at a gage height of 46 feet. The water was out over the bottoms above, and in Richmond it covered the tracks of the Southern Pacific Railroad.

The following measurements were made at Richmond in 1902:

August 2: Gage height, 28.1; discharge, 48,400 second-feet.
August 6: Gage height, 31.9; discharge, 60,470 second-feet.
August 19: Gage height, 7.1; discharge, 5,800 second-feet.

LITTLE RIVER AND ITS TRIBUTARIES.

The Sulphur Fork of the Lampasas rises in the town of Lampasas in two springs, the Hancock and the Hanna, with a joint flow as determined on August 18, 1902, by T. U. Taylor of 9 second-feet. Of this amount the Hancock had 7.6 second-feet and the Hanna 1.4. This is probably the least flow of the springs. These springs are fully described in Water Supply Paper No. 50, page 335. The Lampasas, the Salado, and the Leon unite southeast of Belton, in Bell County, at the "Three Forks," forming the Little River. The Salado rises in the village of Salado, 9 miles south of Belton, from springs that bear a striking resemblance to those of the Edwards formation. The measurement at Salado on December 19, 1902, can be regarded as the minimum flow, as there had been no rains for many months. The Salado has a reliable flow of 13 second-feet at its head and it is slightly reenforced lower down. At one time there were eleven different power plants in operation along this short stream, but at present there are

only three in active operation. Summer's mill, 2 miles above the "Three Forks," derives its power from a 10-foot dam. Dulaney's mill, 1 mile farther up the stream, derives its power from a dam 8 feet high, while Stinnett's flour mill, 6 miles farther up, gets an 18-foot head by means of a mill race 1 mile long. Below the "Three Forks" the river is known as Little River. It has two reliable streams in the Lampasas and Salado to feed it, and its flow is reliable, but probably on account of danger from overflows no attempts have been made to utilize its energy in power plants. Three irrigation plants have been located on the Little River within the last year in the neighborhood of Cameron.

San Gabriel River.—The San Gabriel River rises in Burnett County, and flows easterly through Williamson County, and joins Little River 10 miles north of Rockdale. Its waters are used for irrigation and power purposes near Georgetown and Taylor.

Miscellaneous measurements in Little River Basin.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
December 18	Salado	Dulaney's Mill	29
December 19	do	Salado	13
August 18	Sulphur Fork of Lampasas	Lampasas	9
February 15	San Gabriel	Jonah	34

COLORADO RIVER (OF TEXAS) DRAINAGE BASIN.

The Colorado River rises in the extreme western portion of the State, within a few miles of the eastern boundary of New Mexico, and flows in a general southeasterly direction, emptying into the Gulf of Mexico in Matagorda County. The drainage area above Austin is 37,000 square miles, and above Columbus it is 40,000 square miles, and it extends into the corner of New Mexico. Its main tributaries are the Concho, the San Saba, and the Llano. The Concho has a reliable flow above its junction with the Colorado, and if the stream below the junction were to receive its name from the one that contributed the most water the river below the junction would be known as the Concho instead of the Colorado. The Concho furnishes water for irrigation and water power, and supports in Irion and Tom Green counties some excellent irrigation systems, described in Water Supply Paper No. 71. The San Saba and the Llano rivers are described in the same paper.

The Colorado at Austin emerges from a canyon. From Austin to the Gulf it traverses a rather flat country, and its waters are utilized for many power plants, and during the season of 1902 60,000 acres of rice were sowed in the counties of Colorado, Wharton, and Matagorda, under canals that obtained their water from the Colorado.

Under the direction of Thomas U. Taylor, the United States Geological Survey is maintaining gaging stations in this basin at Columbus and Austin, Tex. During 1902 miscellaneous measurements were made by Mr. Taylor at several other places, as stated hereafter.

COLORADO RIVER AT COLUMBUS, TEX.

A gaging station was established at Columbus, Tex., on the Colorado River, in December, 1902. The zero of the gage is 50 feet below the top of the downstream pier on the west side of the river. A gage has been marked off by the county officers on this pier, but the observer for the United States Geological Survey uses a tagged chain, with lead weight for a sounder. The flood of 1900 was the highest known at Columbus, and it reached the gage height of 38.6 feet.

The following measurements were made on the Colorado at Columbus in 1902:

August 2: Gage height, 32.0 feet; discharge, 36,000 second-feet.
August 4: Gage height, 13.4 feet; discharge, 6,800 second-feet.
August 7: Gage height, 12.6 feet; discharge, 4,300 second-feet.
December 27: Gage height, 3.5 feet; discharge, 1,200 second-feet.

COLORADO RIVER AT AUSTIN, TEX.

Gage heights were first taken on the crest of the Austin dam on August 13, 1895, and were continued from that date until the failure of the dam occurred in April, 1900. The first discharge measurement was made on December 21, 1897. In February, 1899, the gage was placed on the Congress Avenue Bridge south of the city. This gage consists of a plain staff attached to a bath house. The observer is W. Peterson. The bench mark is on the first flange above the cribwork of the north pier of the highway bridge. Its height is 4.78 feet above the zero of the gage. Measurements of discharge are made in a narrow place in the river about one-fourth mile above this point. The flood of April 7, 1900, carried away the great masonry dam at Austin. This flood was general over southwest Texas, but its only disaster was limited to the demolition of that structure. A full discussion of this failure will be found in Water Supply Paper No. 40.

Prior to the flood of April 7, 1900, the discharge of the river at the station below the dam was at low stages absolutely under the control of the turbines at the power house at the dam; and measurements made opposite the city, at the station between the two bridges, did not give

the unobstructed flow of the river. Since the destruction of the dam, measurements have been made at the station a fourth of a mile above the highway bridge on Congress avenue.

Discharge measurements of Colorado River at Austin, Tex.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 20	C. N. Campbell	2.10	497
February 17	do	1.99	471
March 15	do	2.50	962
April 9	do	1.70	376
June 20	T. W. Taylor	1.40	252
June 21	do	1.32	186
Do	do	1.32	215
June 23	do	1.34	211
June 28	A. A. Cother	1.20	180
June 30	do	1.19	176
October 24	T. W. Taylor	1.55	293
October 25	do	1.50	282
October 28	A. A. Cother	1.45	286
October 30	do	1.40	293
November 4	do	4.10	3,600
November 5	do	3.20	1,717
November 6	do	2.60	1,216
November 11	do	2.40	1,100
November 17	do	6.80	13,917
November 18	do	6.20	11,650
November 21	do	3.10	1,686
November 22	do	8.40	20,083
November 24	do	9.80	26,246
November 25	do	7.40	16,613
November 27	do	6.50	12,845
December 2	do	4.00	2,793

Daily gage height, in feet, of Colorado River at Austin, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.85	1.90	1.83	1.90	1.95	3.25	2.85	10.10	1.55	2.50	1.40	3.15
2	1.85	1.90	1.80	2.00	1.85	5.15	2.25	8.60	60	2.40	1.40	3.70
3	1.85	1.90	1.80	1.90	1.75	4.00	4.60	5.80	1.60	4.35	1.50	4.85
4	1.85	1.95	1.75	1.80	1.85	3.45	5.60	4.50	1.90	5.00	4.15	4.35
5	1.85	2.00	1.70	1.73	1.95	2.90	4.05	4.00	3.45	4.05	3.10	3.70
6	1.85	2.00	1.70	1.73	1.85	2.75	3.15	3.55	3.80	3.65	2.70	3.30
7	1.85	1.95	1.70	1.70	1.95	2.45	2.75	3.20	3.00	3.45	3.25	3.05
8	1.85	1.98	1.70	2.05	1.95	2.35	2.50	3.05	3.45	2.90	3.30	2.95
9	1.90	2.00	1.70	1.75	3.20	2.20	2.35	3.00	3.50	2.55	2.85	2.75
10	1.90	2.00	1.70	1.70	3.70	2.15	2.20	3.05	5.30	2.35	2.55	2.65
11	1.90	2.00	1.80	1.60	3.25	2.05	2.15	2.60	4.15	2.20	2.40	2.60
12	1.90	2.00	1.80	1.53	2.90	2.00	1.95	2.50	3.45	2.10	2.30	2.50
13	1.95	2.00	4.00	3.10	2.65	1.85	1.80	2.55	3.15	1.95	2.35	2.50
14	1.95	1.90	3.10	4.15	2.45	1.70	2.65	2.70	2.85	1.90	3.15	2.42
15	1.95	2.00	2.60	5.10	2.35	1.60	2.35	2.55	2.06	1.80	2.45	2.35
16	1.98	2.00	2.05	6.15	2.20	1.60	2.20	2.40	2.45	1.75	2.15	2.30
17	2.00	1.95	3.20	4.85	2.15	1.63	2.25	2.20	2.35	1.70	4.70	2.25
18	2.00	1.95	2.90	4.20	2.15	1.60	2.05	2.10	2.20	1.70	5.30	2.25
19	2.00	1.95	2.70	3.30	5.25	1.50	3.15	2.00	2.10	1.60	4.15	2.00
20	2.10	1.90	2.50	3.15	8.05	1.43	2.40	2.00	2.05	1.60	3.30	2.00
21	2.10	1.90	2.38	2.95	8.85	1.40	2.25	1.90	2.00	1.60	3.00	2.15
22	2.00	1.90	2.30	2.75	5.95	1.38	2.10	1.92	1.90	1.60	5.75	2.10
23	2.00	1.90	2.23	2.60	4.35	1.35	2.15	1.82	2.35	1.55	9.85	2.10
24	2.00	1.88	2.20	2.50	3.90	1.30	2.25	1.72	2.70	1.55	10.90	2.05
25	1.95	1.85	2.10	2.40	3.40	1.30	5.70	1.70	2.40	1.50	7.40	2.00
26	1.93	1.85	2.15	2.33	3.15	1.30	9.10	1.70	3.05	1.45	8.	1.95
27	1.90	1.85	2.00	2.30	2.95	1.30	11.10	1.67	2.95	1.45	6.75	1.95
28	1.90	1.85	1.93	2.20	3.10	20	11.85	1.65	2.80	1.42	4.90	1.90
29	1.90	.....	1.85	2.10	3.20	30	10.65	1.60	3.25	1.40	4.20	1.90
30	1.90	.....	1.80	2.00	3.00	2.05	10.35	1.60	2.90	40	3.55	1.90
31	1.90	.....	1.80	.....	2.85	.....	10.65	1.55	.....	40	.....	1.95

Rating table for Colorado River at Austin, Tex., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.2	180	3.6	2,480	6.0	10,850	8.4	20,450
1.4	240	3.8	2,890	6.2	11,650	8.6	21,250
1.6	320	4.0	3,340	6.4	12,450	8.8	22,050
1.8	410	4.2	3,865	6.6	13,250	9.0	22,850
2.0	520	4.4	4,490	6.8	14,050	9.2	23,650
2.2	650	4.6	5,250	7.0	14,850	9.4	24,450
2.4	820	4.8	6,050	7.2	15,650	9.6	25,250
2.6	1,020	5.0	6,850	7.4	16,450	9.8	26,050
2.8	1,240	5.2	7,650	7.6	17,250	10.0	26,850
3.0	1,490	5.4	8,450	7.8	18,050		
3.2	1,780	5.6	9,250	8.0	18,850		
3.4	2,110	5.8	10,050	8.2	19,650		

Estimated monthly discharge of Colorado River at Austin, Tex.

[Drainage area, 37,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	580	435	480	29,494	0.01	0.01
February	520	435	483	26,836	.01	.01
March	3,340	360	732	45,025	.02	.02
April	11,450	300	1,711	101,827	.05	.06
May	22,250	385	3,052	187,652	.08	.09
June	7,450	180	883	52,552	.02	.02
July	31,250	410	7,148	439,517	.19	.22
August	27,250	300	2,827	173,841	.08	.09
September	2,890	300	1,503	89,460	.04	.04
October	6,850	240	1,019	62,684	.03	.03
November	30,450	240	5,623	334,594	.15	.17
December	6,250	460	1,230	75,626	.03	.03
The year	31,250	180	2,224	1,619,108	.06	.79

Miscellaneous measurements on Colorado River.

Date.	Locality.	Discharge.
1902.		*Sec.-feet.*
June 19	Marble Falls	219
June 27	do	145
August 17	Ballinger	104

BARTON SPRINGS NEAR AUSTIN, TEX.

These springs are about 2 miles from the court-house at Austin. There are at present two distinct groups of springs that unite one-fourth mile below the stone bridge and form the main channel. The flow of these springs has responded to the rainfall on the Edwards Plateau with unfailing regularity. The Walsh spring on the south side of the stream which formerly ran a mill was dry for several years, but in 1900, a year of heavy rainfall, it revived and continued flowing for about a year, but during the whole of 1902 no water issued from this spring. The following measurements have been made of the flow of the springs:

Miscellaneous measurements of Barton Springs.

Date.	Hydrographer.	Discharge.
		Sec.-feet.
1894	C. C. Babb	17
1895	do	25
March, 1898	T. U. Taylor	20
May, 1898	do	30
August, 1900	do	69
December, 1900	do	33
June, 1902	do	19
August, 1902	do	19

LLANO RIVER, TEXAS.

The Llano River rises in Sutton County and flows east to its junction with the Colorado. Just below Junction City, in Kimble County, the North and South forks unite and form the main Llano.

The main Llano River is joined by the Johnson Fork of the Llano below Junction City. The water in this fork is almost exhausted, before it reaches the main Llano, by several small irrigation plants that derive their waters from it. The measurement of August 13, 1902, on the South Llano was stated by the mill owner and operator just south of the town to be at the lowest stage, and this is highly probable, as no rains of any account had fallen for some time. While the South Llano is much shorter than the North Llano, yet the North Llano on the same date was not flowing at their junction. The South Llano could easily supply sufficient water for an irrigation system of 6,000 acres, and the land that could be brought under ditch is rich and well placed for easy irrigation.

The capacity of the Llanos has not been developed to much extent either for power or irrigation purposes. Power plants are located at Junction City, 2 miles above the town of Llano, and at Llano. Its use for irrigation purposes is confined to the county of Kimble.

There are more individual irrigation plants in Kimble County fed by the Llano and its tributaries than in any other county in Texas, as can be seen by referring to Water Supply Paper 71. There are four water-power plants on the Llanos, but only three are in active operation at present. At Junction City, a dam about one foot high, constructed of logs and loose rocks, deflects part of the flow of the South Llano into a ditch whose bed is on the same level with that of the river. The ditch is 10 feet wide, 4 feet deep, and about 3 furlongs in length. The ditch follows the foothills to the fore bay or flume

100 feet long, 6 feet wide, and 6 feet deep. The power is develop by a 30-inch Leffel turbine, and is used to run a gristmill, a cott gin of 70 saws, and to supply a tank 80 feet above the level of t water in the ditch. The tank is used as a part of the waterworks f the town of Junction. The water emerges from the turbine and flo back under the flume for about 60 feet, when it turns sharply to t east and is conducted back to the river. In addition to the pow developed, there is a plan on foot to install an irrigation system 6,000 acres. The main canal will be taken out of the river abo Junction and will follow the foothills west of town and then cr the North Llano by an invert, and irrigate lands on the north side the main Llano east of the town.

While there are many localities on the Llano between Junction a the town of Llano where power plants could be developed, yet attempts have been made to construct additional plants except ne the town of Llano. At Llano there are conditions for a good wat power plant. Just north of the town a small plant is at present us in running the waterworks, the electric-light plant, and the flour mi The dam is constructed partly of stone and partly of wood. It is bu on a turtleback formation of granite that would afford an excelle foundation for a masonry dam. All the necessary factors for a su cessful power plant—the foundation, the water, the finest stone in t world, and good railroad facilities—are here in abundance and on await capital.

Miscellaneous measurements on the Llano and its tributaries.

Date.	Stream.	Locality.	Dis char
1902.			*Sec.-f*
June 26	Llano	Above Llano	
August 13	Johnson Fork	1 mile above Segovia	
Do	South Llano	One-fourth mile below Junction City.	
August 14	Bear Creek	Morales farm	

SAN SABA RIVER, TEXAS.

The San Saba River rises in two springs near Fort McKavett, in western part of Menard County, and flows in an easterly direction over 100 miles to its junction with the Colorado. Between F McKavett and Menardville the river is fed by many springs, some which are utilized in small irrigation systems before their waters j those of the San Saba. The largest of these springs is known as

Wilkinson spring, and is situated above Menardville, on the farm of W. J. Wilkinson. It forms the headwaters of Clear Creek. This stream is only about 3 miles long. Its waters are only partially utilized for irrigation purposes, but it would easily irrigate 1,500 to 2,000 acres. A resident of thirty years states that the flow of this stream is greater in the summer than in the winter. However, the variation is rather slight, so that its capacity for irrigation or power purposes would not be subject to large fluctuations.

Four miles above Menardville the Noyes ditch, 9 miles long, is taken out of the San Saba and deflects most of the normal flow. This ditch feeds an irrigation system both above and below the town of Menardville. Above Menardville the water of the San Saba is used for the irrigation systems of Byers and Striegler and for the Noyes system, which lies above and below Menardville. The Sieker and the Kitchen ditches, 2 and 5 miles, respectively, below Menardville, are taken from the San Saba. For a full description of these irrigation systems see Water Supply Paper No. 71.

Twelve miles below Menardville the river enters the canyons, which it traverses for 50 miles. The canyons finally widen into rich valleys at a point known as "The Narrows," 17 miles above the town of San Saba, opposite the ranch of Hilliard Doran. The measurement made on June 24 can be relied upon as the least flow of the San Saba, as no rain of any consequence had fallen on its drainage area for nearly two years. While the flow at Fort McKavett is more than this, and while Clear Creek and the smaller streams swell this flow above Menardville to double this amount, the irrigation systems in Menard County practically take all the water out of the river. When this measurement of 25 second-feet was made at "The Narrows" the river was reported as not flowing above the mouth of Brady Creek. Twelve miles above San Saba the Sloan spring emerges from the foothills of the Edwards plateau. It has a capacity of 9 second-feet, and its waters are utilized in one of the most effective irrigation systems in Texas.

So far the waters of the San Saba have not been used for power purposes on the main stream, but in its course there are many excellent sites for dams that would make practical use of the waste potential energy.

Miscellaneous measurements on the San Saba and its tributaries.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
August 14	San Saba	1 mile below Fort McKavett.	26
Do	Clear Creek	9 miles above Menardville.	25
August 15	San Saba	North of Menardville court-house.	8
Do	Noyes Ditch	Near M. E. Church, Menardville.	28
June 24	San Saba	Doran's ranch	25
June 25	do	1 mile below Doran's ranch.	28
Do	do	Barnetts Ford, above San Saba.	28
June 24	Mill Creek	San Saba	8

GUADALUPE RIVER DRAINAGE BASIN.

The Guadalupe River rises in the southern central part of Texas, flows southeast, and empties into San Antonio Bay. During the summer of 1902 its discharge was the least in its observed history, causing much loss above New Braunfels, where half a dozen power plants were forced to shut down or to run on short time. The flow at this time was so low that special efforts were made to obtain measurements at several points along its course. The results of these measurements are shown in the accompanying table.

Under the direction of Thomas U. Taylor, the U. S. Geological Survey is maintaining a station in this basin near Cuero, Tex.

GUADALUPE RIVER NEAR CUERO, TEX.

This station was established by Thomas U. Taylor December 26, 1902. It is located at the dam of Carl Buchel's power house, 3 miles north of Cuero, Tex. The gage is a plain staff graduated to feet and tenths. It is mounted on the wall of the power house near the dam, and is read twice daily by Carl Buchel. The initial point for sounding is on the left bank. The channel is straight for about one-fourth of a mile above and 400 feet below the station. The right bank is low and liable to overflow; the left bank is high and rocky. The bed of the stream is of clay. The bench mark is on the crest of the dam. Its elevation is the same as the zero of the gage.

The Guadalupe, while the best water-power stream in Texas, has a drainage area above Cuero of only 5,100 square miles. Its efficiency is due almost entirely to the canal at New Braunfels. Below New Braunfels the largest tributary is the San Marcos River.

Miscellaneous measurements in the Guadalupe River drainage basin.

Date.	Stream.	Station.	Discharge.
1902.			*Sec.-feet.*
August 29	Gaudalupe	Comfort	7
August 28	do	Near Walhalla	11
Do	do	6 miles above New Braunfels.	9
August 26	do	North of New Braunfels, near cemetery crossing.	13
August 27	do	One-fourth mile above International and Great Northern R. R. bridge.	342
August 30	do	Below Erskine Falls	355
February 22	Comal	Landa Mill Race and Comal Spring Creek.	333
August 26	do	do	318
August 12	Johnsons Fork	On Kerrville and Junction City road crossing.	9
February 22	San Marcos	Prairie Lea	149
September 9	do	Westerfield Ford	150
March 12	San Antonio	San Antonio	7
October 21	do	Hot Wells	34

RIO GRANDE DRAINAGE BASIN.

The Rio Grande rises in southern Colorado, in the Rocky Mountains, flows south through New Mexico and thence southeast, forming the boundary between Texas and Mexico. Pecos River, which rises in northern New Mexico and flows south across eastern New Mexico and western Texas, is its principal tributary from the north. The Conchos River is its principal tributary from the Mexican side. The determination of the amount of water in the Rio Grande is of importance, both on account of its use in irrigation and from its bearing upon interstate and international distribution of water. The New Mexico and Texas stations are maintained by the International (Water) Boundary Commission, and the data are furnished by W. W. Follett, consulting engineer for the Commission. On account of the shifting character of the river beds at the international (water) boundary stations, no rating tables have been prepared. The estimated monthly discharges are from daily discharges, computed directly from the discharge measurements. The following list includes the stations in the Rio Grande drainage basin:

Rio Grande at Eagle Pass, Tex.
Las Moras Creek.
San Felipe Creek.
Rio Grande below mouth of Devils River, Texas.
Devils River at Devilsriver, Tex.

Pecos River at Moorhead, Tex.
Pecos River, Margueretta flume, and West Valley ditch, near Pecos, Tex.
Rio Grande at Langtry, Tex.
Rio Grande below Presidio, Tex.
Rio Grande above Presidio, Tex.
Rio Grande near Fort Hancock, Tex.
Rio Grande near El Paso, Tex.
Rio Grande near San Marcial, N. Mex.
Rio Grande at water tank; Buckman, near Rio Grande, N. Mex.
Rio Grande at Embudo, N. Mex.
Rio Grande near Cenicero, Colo.
Rio Grande near Del Norte, Colo.

RIO GRANDE AT EAGLE PASS, TEX.

This station was established in April, 1900, by the International (Water) Boundary Commission. It is a half mile above the highway bridge between Eagle Pass and Ciudad Porfirio Diaz, Mexico, and about 540 miles below El Paso, Tex. During 1902 the following measurements of discharge were made by O. B. Powell, D. Griggs, and R. F. Dowe:

Discharge measurements of the Rio Grande at Eagle Pass, Tex.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
January 3	2.3	2,041	March 29	1.8	1,495
January 7	2.3	1,945	April 1	1.7	1,437
January 10	2.5	2,253	April 4	1.7	1,314
January 13	2.5	2,304	April 8	1.7	1,270
January 17	2.4	2,152	April 12	1.7	1,347
January 25	2.2	1,888	April 15	2.75	2,976
January 28	2.2	1,848	April 19	2.0	1,633
January 31	2.2	1,828	April 23	1.7	1,377
February 4	2.2	1,965	April 26	1.7	1,325
February 8	2.2	2,017	April 29	1.7	1,331
February 11	2.2	2,054	May 3	1.6	1,[illegible]
February 15	2.2	1,957	May 5	4.65	8,[illegible]
February 18	2.2	2,034	May 10	2.2	1,[illegible]
February 22	2.1	1,916	May 13	2.0	1,[illegible]
February 25	2.1	1,954	May 17	1.9	1,[illegible]
March 1	2.0	1,901	May 19	8.0	[a] 34,[illegible]
March 8	1.9	1,826	May 21	2.95	2,6[illegible]
March 11	1.9	1,600	May 23	2.3	2,1[illegible]
March 15	1.9	1,550	May 26	2.1	1,9[illegible]
March 18	1.8	1,478	May 30	1.9	1,7[illegible]
March 22	1.8	1,415	June 3	2.0	1,7[illegible]
March 25	1.8	1,431	June 7	1.8	1,49[illegible]

[a] Partly estimated.

Discharge measurements of the Rio Grande at Eagle Pass, Tex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
June 10	1.7	1,326	September 26	3.15	4,423
June 14	2.2	1,960	September 29	2.9	3,890
June 17	1.9	1,517	October 1	2.9	3,826
June 21	2.2	2,207	October 3	3.05	4,183
June 24	2.0	1,544	October 6	3.5	5,157
June 28	1.9	1,462	October 8	2.9	3,743
July 1	1.8	1,369	October 10	2.6	3,130
July 2	3.7	4,248	October 13	3.0	4,085
July 7	1.8	1,360	October 15	2.9	3,356
July 10	2.0	1,592	October 17	2.6	3,019
July 12	2.9	3,027	October 20	2.5	2,460
July 15	4.75	7,906	October 22	2.4	2,335
July 17	3.6	4,122	October 25	2.3	2,270
July 19	3.3	3,552	October 27	2.3	2,263
July 22	3.55	4,495	October 29	2.2	2,078
July 24	4.5	7,404	October 31	2.2	2,084
July 26	7.5	[a] 22,980	November 3	2.8	3,175
July 28	6.4	16,676	November 5	2.5	2,671
July 30	6.4	17,283	November 7	3.0	3,920
August 2	4.85	9,819	November 10	2.4	2,428
August 4	4.3	7,741	November 12	2.2	2,279
August 7	3.5	4,987	November 14	2.1	2,086
August 9	3.55	5,210	November 17	2.1	1,969
August 11	3.0	3,915	November 19	2.1	1,963
August 15	5.2	9,600	November 21	2.55	2,632
August 19	4.1	6,050	November 23	2.1	2,035
August 21	3.9	5,574	November 26	2.1	2,056
August 23	3.9	5,523	December 4	2.1	2,257
August 26	4.4	7,388	December 6	2.1	2,354
August 28	4.7	8,305	December 9	2.2	2,542
August 30	4.0	6,166	December 11	2.2	2,582
September 2	5.9	14,448	December 13	2.2	2,559
September 4	5.0	8,649	December 16	2.2	2,572
September 9	7.05	25,740	December 18	2.1	2,420
September 10	8.7	30,902	December 20	2.2	2,557
September 13	7.7	25,612	December 23	2.2	2,494
September 18	4.6	8,884	December 26	2.1	2,419
September 20	4.1	8,046	December 29	2.1	2,402
September 22	4.85	10,644	December 31	2.1	2,398
September 24	3.5	5,542			

[a] *Partly estimated.*

Daily gage height, in feet, of the Rio Grande at Eagle Pass, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.											
1	2.30	2.20	2.00	1.70	1.70	2.15	1.80	5.35	5.25	2.90	2.20
2	2.30	2.20	2.00	1.70	1.70	2.10	3.65	4.90	5.75	3.00	2.65
3	2.30	2.20	2.00	1.70	1.60	2.05	2.35	4.55	5.10	3.10	2.80
4	2.30	2.20	2.00	1.70	3.95	1.95	1.95	4.25	4.95	3.20	2.55
5	2.30	2.20	1.90	1.70	4.70	1.90	1.85	4.20	5.30	3.00	2.50
6	2.30	2.20	1.90	1.70	3.15	1.80	1.80	3.90	5.90	3.40	2.65
7	2.30	2.20	1.90	1.70	2.75	1.80	1.75	3.55	5.90	3.15	2.95
8	2.30	2.20	1.90	1.70	2.45	1.80	1.70	3.80	6.25	2.85	2.75
9	2.45	2.20	1.90	1.70	2.35	1.75	1.95	3.70	7.25	2.65	2.55
10	2.50	2.20	1.90	1.70	2.15	1.70	1.95	3.35	8.60	2.55	2.40
11	2.50	2.20	1.90	1.70	2.00	1.70	2.30	3.05	8.90	2.45	2.30
12	2.50	2.20	1.90	1.70	2.00	1.70	2.90	3.00	8.00	2.50	2.20
13	2.50	2.20	1.90	1.70	2.00	1.90	2.75	2.95	7.60	3.00	2.20
14	2.50	2.20	1.90	1.85	2.00	2.25	4.45	3.20	6.95	2.90	2.10
15	2.50	2.20	1.90	2.40	1.90	2.05	4.60	5.15	6.00	2.85	2.10
16	2.45	2.20	1.90	2.45	1.90	2.00	3.80	4.35	5.35	2.75	2.15
17	2.40	2.20	1.80	2.15	1.90	1.90	3.55	4.05	4.90	2.65	2.20
18	2.40	2.20	1.80	2.00	4.45	2.20	3.30	3.95	4.60	2.55	2.10
19	2.40	2.20	1.80	2.00	7.35	2.00	3.30	4.10	4.40	2.50	2.10
20	2.30	2.20	1.80	1.85	3.75	1.90	3.30	4.10	4.00	2.50	2.10
21	2.30	2.10	1.80	1.80	2.75	2.20	3.20	3.85	3.85	2.50	2.40
22	2.30	2.10	1.80	1.80	2.35	2.30	3.35	3.65	4.85	2.45	2.10
23	2.30	2.10	1.80	1.75	2.30	2.25	3.30	3.85	4.35	2.40	2.10
24	2.30	2.10	1.80	1.70	2.25	2.00	4.05	3.75	3.50	2.40	2.10
25	2.20	2.10	1.80	1.70	2.20	1.90	5.00	3.90	3.30	2.30	2.25
26	2.20	2.10	1.80	1.70	2.10	1.90	7.40	4.25	3.15	2.30	2.20
27	2.20	2.10	1.80	1.70	2.10	2.00	6.45	4.85	2.95	2.30	2.00
28	2.20	2.00	1.90	1.70	2.00	1.90	6.30	4.65	2.90	2.30	2.20
29	2.20	.....	1.80	1.70	1.95	1.85	6.40	4.25	2.90	2.20	2.15
30	2.20	.....	1.80	1.70	1.90	1.80	6.35	4.00	2.90	2.20	2.15
31	2.20	.....	1.80	.....	2.30	.....	5.80	1.55	.....	2.20	.....

Estimated monthly discharge of the Rio Grande at Eagle Pass, Tex.

Month.	Discharge in second-feet.			Total in a feet.
	Maximum.	Minimum.	Mean.	
January	2,300	1,830	2,052	126
February	2,050	1,830	1,973	109
March	1,900	1,420	1,606	98.
April	2,260	1,270	1,448	86,
May	29,200	1,260	3,382	207,
June	2,330	1,330	1,648	98,
July	22,400	1,270	6,094	374,
August	12,140	3,800	6,539	402,
September	32,000	3,890	12,868	765,
October	4,920	2,080	3,070	188,
November	3,800	1,930	2,385	141,
December	8,400	2,260	2,904	178,
The year	32,000	1,260	3,831	2,778,

LAS MORAS CREEK, TEXAS.

Las Moras Creek, which rises in the town of Brackettville, Kinney County, Tex., and empties into the Rio Grande about 25 miles above Eagle Pass, has had a variable record since measurements have been made upon it. In December, 1895, C. C. Babb found a total discharge of 21 second-feet. In June, 1898, the "Brackett flood" occurred, as described in Water-Supply Paper No. 50, page 344, and Las Moras showed an increased flow up to the latter part of 1901. The flow was measured by T. U. Taylor in June, 1899, when it had a discharge of 60 second-feet at Mulligan's bend, one-fourth mile below the courthouse; in ———, 1900, when a flow of 51 second-feet was found at the same section; in December, 1901, when a flow of —— second-feet was obtained, and in 1902 two checked measurements on September 2 and 3 each gave a discharge of only 11 second-feet.

SAN FELIPE CREEK, TEXAS.

San Felipe Creek has its source in four large springs. These springs are all above the Southern Pacific Railroad bridge, 1 mile east of Del Rio, at distances from 200 yards to 2 miles. Measurements have been made on the San Felipe since December, 1895, when C. C. Babb found a joint discharge on the creek and of Madre ditch (which includes the total flow of the springs) to be 99 second-feet. The following measurements have since been made by and under the direction of T. U. Taylor: In June, 1899, a joint flow of 84 second-feet; September, 1900, a joint flow of 149 second-feet; in December, 1901, a flow of 150 second-feet, and in September, 1902, a flow of 115 second-feet were obtained. The variation in the flow is caused by an increased rainfall in the Edwards Plateau to the north of Del Rio. An increased flow is found in all of the outlets of the underground waters of the plateau which stretches from the Southern Pacific Railroad north to the Texas Pacific Railroad. The crest of increased flow follows the increased rainfall in the highlands to the north.

RIO GRANDE BELOW MOUTH OF DEVILS RIVER, TEXAS.

This station was established in April, 1900, by the International (Water) Boundary Commission. It is alongside the Southern Pacific Railway track, about a half mile below the mouth of Devils River and about 480 miles below El Paso.

Discharge measurements of the Rio Grande near Devilsriver, Tex.

[Made by James F. Hague, J. D. Dillard, and A. L. Wilcox.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Dis
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Sec*
January 6	3.5	2,152	July 8	3.55	
January 10	3.9	2,944	July 12	4.3	
January 14	3.8	2,591	July 15	5.75	
January 19	3.7	2,147	July 20	4.7	
January 23	3.5	2,107	July 24	6.8	
January 26	3.5	1,955	July 29	9.1	
January 30	3.5	1,865	August 2	6.5	
February 5	3.5	1,943	August 6	5.3	
February 10	3.5	2,034	August 11	4.85	
February 13	3.5	2,048	August 15	6.85	
February 17	3.5	2,071	August 19	5.6	
February 20	3.5	2,172	August 23	5.7	
February 24	3.5	2,037	August 28	6.3	
March 2	3.4	1,826	September 1	7.15	
March 5	3.3	1,697	September 5	8.7	
March 9	3.3	1,592	September 9	11.75	
March 12	3.3	1,716	September 13	9.65	
March 16	3.3	1,672	September 17	6.35	
March 20	3.2	1,579	September 19	6.1	
March 24	3.25	1,622	September 23	5.35	
March 28	3.1	1,496	September 27	4.85	
April 3	3.1	1,438	October 2	4.7	
April 8	3.1	1,405	October 6	5.0	
April 11	3.1	1,379	October 10	4.4	
April 14	4.6	4,393	October 14	4.65	
April 19	3.25	1,488	October 18	4.35	
April 26	3.1	1,253	October 22	4.2	
May 1	3.1	1,243	October 25	4.15	
May 6	3.4	1,671	October 30	4.05	
May 10	3.2	1,379	November 2	4.75	
May 16	3.3	1,558	November 6	4.85	
May 20	3.95	2,654	November 10	4.1	
May 24	3.4	1,600	November 14	3.95	
May 29	3.3	1,426	November 18	3.9	
June 3	3.4	1,620	November 22	3.9	
June 7	3.3	1,398	November 26	3.9	
June 11	3.3	1,471	December 2	3.9	
June 15	3.5	1,807	December 8	4.0	
June 19	3.4	1,662	December 13	3.95	
June 24	3.35	1,556	December 18	3.9	
June 28	3.4	1,502	December 23	3.9	
July 3	3.4	1,497	December 30	3.9	

Daily gage height, in feet, of the Rio Grande near Devilsriver, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.60	3.50	3.50	3.10	3.10	3.80	6.25	6.85	7.35	4.70	4.35	3.90
2	3.60	3.50	3.40	3.10	3.10	3.50	3.75	6.45	7.25	4.70	4.60	3.90
3	3.60	3.50	3.50	3.10	3.10	3.40	3.40	6.20	7.25	5.10	4.35	3.85
4	3.60	3.50	3.45	3.10	4.80	3.40	3.35	5.95	7.30	4.80	4.35	3.80
5	3.55	3.50	3.30	3.10	3.75	3.30	3.30	5.65	8.65	5.00	4.30	3.95
6	3.50	3.50	3.30	3.10	3.55	3.30	3.30	5.25	8.00	4.95	4.85	4.05
7	3.50	3.50	3.30	3.10	3.60	3.30	3.30	5.90	8.60	4.65	4.55	4.05
8	3.50	3.50	3.30	3.10	3.35	3.30	3.50	5.50	9.70	4.45	4.35	4.00
9	3.90	3.50	3.30	3.10	3.20	3.30	3.40	4.95	11.65	4.40	4.20	3.90
10	3.85	3.50	3.30	3.10	3.20	3.30	4.05	4.75	12.75	4.40	4.10	4.00
11	3.80	3.50	3.30	3.10	3.10	3.35	4.40	4.70	10.90	4.35	4.05	4.00
12	3.80	3.50	3.30	3.10	3.10	3.60	4.20	4.60	10.40	4.75	4.00	4.00
13	3.80	3.50	3.30	3.40	3.10	3.75	5.35	4.50	9.50	4.75	3.90	3.90
14	3.80	3.50	3.30	4.10	3.10	3.65	6.60	7.50	8.45	4.65	3.90	3.90
15	3.70	3.50	3.30	3.70	3.10	3.50	5.60	6.85	7.30	4.55	3.90	3.90
16	3.70	3.50	3.30	3.50	3.20	3.50	5.15	6.00	6.65	4.45	3.90	3.90
17	3.70	3.50	3.30	3.40	3.20	3.50	4.80	6.00	6.35	4.40	3.90	3.90
18	3.70	3.50	3.30	3.40	10.00	3.50	4.85	5.95	6.05	4.35	3.90	3.90
19	3.70	3.50	3.20	3.30	5.60	3.40	4.75	5.60	5.95	4.30	3.90	3.95
20	3.60	3.50	3.20	3.15	3.95	3.90	4.70	5.85	5.50	4.30	3.90	3.90
21	3.60	3.50	3.20	3.10	3.75	3.95	4.95	5.65	6.10	4.20	3.90	3.90
22	3.60	3.50	3.20	3.10	3.45	3.80	4.85	5.65	6.55	4.20	3.90	3.90
23	3.50	3.50	3.20	3.10	3.40	3.50	5.65	5.70	5.30	4.15	3.95	3.90
24	3.50	3.50	3.25	3.10	3.40	3.40	6.50	5.60	5.00	4.10	4.20	3.90
25	3.50	3.50	3.20	3.10	3.65	3.40	10.15	5.95	4.80	4.10	3.95	3.90
26	3.50	3.50	3.10	3.10	3.50	3.40	9.55	6.75	4.90	4.00	3.90	3.90
27	3.50	3.50	3.10	3.10	3.40	3.40	8.00	6.95	4.85	4.05	4.05	3.90
28	3.50	3.50	3.10	3.10	3.40	3.40	8.40	6.20	4.70	4.10	3.90	3.90
29	3.50	.....	3.10	3.10	3.30	3.35	9.20	5.90	4.70	4.10	3.90	3.90
30	3.50	.....	3.10	3.10	4.20	3.30	8.05	6.30	4.70	4.10	3.90	3.90
31	3.50	.....	3.10	.....	4.20	.....	7.55	7.25	.....	4.10	.....	3.90

Estimated monthly discharge of the Rio Grande near Devilsriver, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	2,940	1,860	2,246	138,129
February	2,170	1,880	2,022	112,304
March	1,940	1,500	1,646	101,217
April	3,270	1,250	1,535	91,359
May	23,000	1,240	2,656	163,339
June	2,650	1,400	1,755	104,450
July	18,700	1,360	6,372	391,795
August	12,200	3,460	7,071	434,797
September	35,500	3,700	12,122	721,329
October	4,770	2,150	3,037	186,744
November	3,850	2,030	2,400	142,790
December	2,250	1,930	2,080	127,914
The year	35,500	1,240	3,745	2,716,167

DEVILS RIVER AT DEVILSRIVER, TEX.

This station was established in April, 1900, by the Intern (Water) Boundary Commission. It is opposite the Southern Railway station at Devilsriver. The river is about 50 miles in l has a perennial flow, and during flood periods is subject to fluctuations.

Discharge measurements of Devils River at Devilsriver, Tex.

[Made by James P. Hague, J. D. Dillard, and A. L. Wilcox.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Di
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	S
January 5	2.0	497	July 2	2.0	
January 11	2.1	488	July 11	2.0	
January 18	2.0	495	July 19	2.0	
January 22	2.0	489	July 28	2.1	
January 29	2.0	472	August 5	2.0	
February 6	2.0	490	August 14	2.0	
February 9	2.0	453	August 20	2.0	
February 16	2.0	474	August 28	2.0	
February 23	2.0	505	September 4	2.25	
March 1	2.0	497	September 12	2.2	
March 8	2.0	503	September 16	2.2	
March 17	2.0	493	September 18	2.2	
March 23	2.0	490	September 26	2.15	
March 29	2.0	486	October 5	2.15	
April 4	2.0	479	October 13	2.15	
April 8	2.0	475	October 21	2.1	
April 15	2.0	487	October 29	2.1	
April 25	1.9	438	November 5	2.15	
May 5	2.3	656	November 13	2.15	
May 9	2.0	446	November 22	2.15	
May 19	4.0	2,479	November 26	2.1	
May 23	2.4	742	December 2	2.25	
May 28	2.2	582	December 8	2.15	
June 2	2.2	536	December 13	2.1	
June 14	2.1	483	December 18	2.1	
June 23	2.05	470	December 23	2.05	
June 27	2.0	448	December 30	2.05	

Daily gage height, in feet, of Devils River at Devilsriver, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.00	2.00	2.00	2.00	1.90	2.20	2.00	2.00	2.00	2.10	2.10	2.20
2	2.00	2.00	2.00	2.00	1.90	2.20	2.00	2.00	2.00	2.20	2.40	2.30
3	2.00	2.00	2.00	2.00	1.90	2.20	2.00	2.00	2.00	2.35	2.35	2.20
4	2.00	2.00	2.00	2.00	3.00	2.20	2.00	2.00	2.25	2.25	2.25	2.15
5	2.00	2.00	2.00	2.00	2.40	2.20	2.00	2.00	2.05	2.15	2.15	2.15
6	2.00	2.00	2.00	2.00	2.20	2.20	2.00	2.00	2.00	2.15	2.15	2.15
7	2.00	2.00	2.00	2.00	2.10	2.20	2.00	2.00	3.80	2.15	2.15	2.15
8	2.00	2.00	2.00	2.00	2.00	2.20	2.00	2.00	2.25	2.10	2.15	2.15
9	2.00	2.00	2.00	2.00	2.00	2.20	2.00	2.00	2.20	2.10	2.15	2.15
10	2.00	2.00	2.00	2.00	2.00	2.20	2.00	2.00	2.20	2.10	2.15	2.15
11	2.05	2.00	2.00	2.00	2.00	2.20	2.00	2.00	2.20	2.10	2.15	2.15
12	2.10	2.00	2.00	2.00	2.00	2.10	2.00	2.00	2.20	2.10	2.15	2.10
13	2.10	2.00	2.00	2.20	2.00	2.10	2.00	2.00	2.10	2.10	2.15	2.10
14	2.10	2.00	2.00	2.10	2.00	2.10	2.00	2.00	2.20	2.10	2.15	2.10
15	2.10	2.00	2.00	2.00	2.00	2.10	2.00	2.00	2.20	2.10	2.15	2.10
16	2.10	2.00	2.00	2.00	2.00	2.10	2.00	2.00	2.20	2.10	2.15	2.10
17	2.10	2.00	2.00	2.00	2.00	2.10	2.00	2.00	2.20	2.10	2.15	2.05
18	2.00	2.00	2.00	1.90	5.95	2.10	2.00	2.00	2.20	2.10	2.15	2.10
19	2.00	2.00	2.00	1.90	4.05	2.10	2.00	2.00	2.20	2.10	2.15	2.10
20	2.00	2.00	2.00	1.90	2.95	2.10	2.00	2.00	2.20	2.10	2.15	2.10
21	2.00	2.00	2.00	1.90	2.65	2.10	2.00	2.00	2.20	2.10	2.15	2.10
22	2.00	2.00	2.00	1.90	2.45	2.00	2.00	2.00	2.20	2.10	2.15	2.05
23	2.00	2.00	2.00	1.90	2.40	2.00	2.00	2.00	2.20	2.10	2.15	2.05
24	2.00	2.00	2.00	1.90	2.40	2.00	2.00	2.00	2.20	2.10	2.15	2.05
25	2.00	2.00	2.00	1.90	2.25	2.00	2.00	2.00	2.20	2.10	2.15	2.05
26	2.00	2.00	2.00	1.90	2.20	2.00	2.00	2.00	2.15	2.10	2.10	2.05
27	2.00	2.00	2.00	1.90	2.20	2.00	2.60	2.00	2.15	2.10	2.10	2.05
28	2.00	2.00	2.00	1.90	2.20	2.00	2.15	2.00	2.15	2.10	2.10	2.05
29	2.00	.....	2.00	1.90	2.20	2.00	2.05	2.00	2.15	2.10	2.10	2.05
30	2.00	.....	2.00	1.90	2.20	2.00	2.00	2.00	2.15	2.10	2.10	2.05
31	2.00	.....	2.00	.....	2.20	.....	2.00	2.00	.....	2.10	.....	2.05

Estimated monthly discharge of Devils River at Devilsriver, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	500	470	488	29,990
February	500	450	480	26,638
March	500	490	494	30,367
April	590	440	469	27,907
May	5,380	440	815	50,102
June	560	435	491	29,207
July	880	420	443	27,213
August	430	405	414	25,458
September	2,200	405	510	30,367
October	530	420	433	26,618
November	660	390	436	29,514
December	535	380	414	25,438
The year	5,380	380	491	355,219

PECOS RIVER NEAR MOORHEAD, TEX.

This station was established by the International (Water) Boundary Commission in April, 1900. It is near Moorhead, immediately above the high bridge of the Southern Pacific Railway.

Discharge measurements of Pecos River near Moorhead, Tex.

[Made by James P. Hague, J. D. Dillard, and A. L. Wilcox.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
January 4	1.4	608	June 4	0.7	231
January 8	2.1	967	June 8	.7	231
January 13	2.1	943	June 12	.7	240
January 16	1.9	842	June 17	1.5	543
January 25	1.6	581	June 20	1.1	351
January 28	1.6	536	June 25	1.7	642
February 1	1.6	499	June 29	1.2	394
February 8	1.4	502	July 4	.9	282
February 12	1.65	636	July 9	.8	253
February 15	1.6	612	July 13	.7	237
February 19	1.6	609	July 17	1.7	594
February 22	1.7	638	July 21	2.35	1,067
March 4	1.3	487	July 25	2.9	1,531
March 7	1.3	487	July 30	3.6	2,036
March 11	1.3	457	August 3	4.2	2,763
March 14	1.2	426	August 7	2.45	1,202
March 19	1.2	362	August 12	1.8	729
March 22	1.2	360	August 16	1.9	784
March 26	1.15	344	August 21	2.0	851
March 30	1.1	370	August 25	1.6	579
April 1	1.1	378	August 29	1.3	465
April 6	1.0	343	September 2	1.2	374
April 10	.9	298	September 6	2.05	885
April 13	1.85	718	September 10	1.55	602
April 20	.9	311	September 14	1.85	742
April 25	.9	277	September 18	1.6	630
April 30	.9	250	September 20	1.55	565
May 3	1.4	460	September 25	1.35	477
May 7	1.35	430	September 30	1.3	431
May 11	.9	249	October 4	1.45	464
May 17	.8	235	October 8	1.3	420
May 21	1.1	322	October 12	1.3	423
May 25	.9	255	October 16	1.3	429
May 30	.8	231	October 20	1.3	416

Discharge measurements of Pecos River near Moorhead, Tex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
October 24	1.25	421	November 28	1.3	392
October 28	1.2	404	December 3	1.3	365
November 3	1.5	521	December 7	1.3	375
November 7	1.3	440	December 11	1.55	507
November 11	1.25	423	December 16	1.4	398
November 15	1.3	420	December 22	1.4	420
November 20	1.25	412	December 27	1.4	410

Daily gage height, in feet, of Pecos River near Moorhead, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.40	1.60	1.60	1.10	0.90	1.05	1.25	3.85	1.20	1.20	1.20	1.30
2	1.40	1.30	1.40	1.10	.90	.90	1.10	3.95	1.25	1.25	1.20	1.30
3	1.40	1.30	1.30	1.10	1.20	.80	1.10	4.20	1.80	1.85	1.45	1.30
4	1.40	1.30	1.30	1.00	.90	.70	.90	4.30	1.45	1.40	1.45	1.30
5	1.30	1.30	1.30	1.00	.90	.70	.90	3.35	4.05	1.40	1.35	1.30
6	1.30	1.20	1.30	1.00	1.35	.70	.90	2.70	2.15	1.40	1.30	1.30
7	1.30	1.30	1.30	1.00	1.40	.70	.85	2.40	1.85	1.30	1.30	1.30
8	1.95	1.40	1.30	1.00	1.15	.70	.80	2.25	1.80	1.30	1.30	1.30
9	2.05	1.40	1.30	1.00	1.10	.70	.80	2.05	1.65	1.30	1.35	1.35
10	2.00	1.40	1.30	.90	1.00	.70	.80	1.95	1.75	1.20	1.40	1.55
11	2.00	1.40	1.30	.90	.90	.70	.75	1.85	1.90	1.20	1.30	1.50
12	2.20	1.60	1.30	.90	.90	.70	.70	1.80	2.05	1.30	1.30	1.60
13	2.10	1.65	1.30	2.20	.90	.80	.70	1.80	2.05	1.30	1.30	1.50
14	2.10	1.60	1.20	3.25	.90	.70	.70	1.90	1.85	1.30	1.30	1.50
15	2.10	1.60	1.20	1.60	.90	.60	.75	1.85	1.65	1.20	1.30	1.50
16	1.90	1.60	1.20	1.70	.90	.70	.80	2.00	1.60	1.30	1.20	1.40
17	1.80	1.60	1.20	1.30	.85	1.50	2.00	2.55	1.70	1.30	1.20	1.40
18	1.80	1.60	1.20	1.10	10.40	1.30	2.90	2.50	2.30	1.30	1.20	1.40
19	1.80	1.60	1.20	1.10	1.35	1.10	2.90	2.25	1.75	1.30	1.25	1.40
20	1.60	1.60	1.20	.90	1.10	1.05	2.50	2.15	1.55	1.30	1.30	1.40
21	1.60	1.60	1.20	.90	1.10	1.00	2.30	2.00	1.50	1.30	1.30	1.40
22	1.60	1.70	1.20	.90	1.10	.95	2.30	1.90	1.50	1.30	1.40	1.40
23	1.60	1.70	1.20	.90	1.00	.80	2.30	1.85	1.40	1.30	1.30	1.40
24	1.60	1.70	1.20	.90	.90	1.55	2.50	1.65	1.45	1.20	1.30	1.40
25	1.60	1.60	1.20	.90	.90	1.60	3.00	1.55	1.40	1.20	1.30	1.40
26	1.60	1.60	1.15	.90	.90	1.35	3.35	1.50	1.35	1.20	1.30	1.40
27	1.60	1.60	1.15	.90	.90	1.20	3.50	1.40	1.30	1.20	1.30	1.40
28	1.60	1.60	1.15	.90	.90	1.05	3.50	1.35	1.30	1.20	1.30	1.40
29	1.60	.....	1.15	.90	.80	1.20	3.55	1.30	1.30	1.20	1.30	1.40
30	1.60	.....	1.10	.90	.80	1.05	3.60	1.25	1.30	1.20	1.30	1.40
31	1.60	.....	1.10	.....	1.20	.....	3.75	1.20	.....	1.20	.....	1.40

Estimated monthly discharge of Pecos River near Moorhead, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	1,000	450	675	41,514
February	640	430	559	31,041
March	610	340	421	25,884
April	1,760	250	411	24,466
May	11,100	230	640	39,342
June	590	210	319	18,952
July	2,160	235	885	54,387
August	2,880	425	1,074	66,020
September	2,370	375	678	40,334
October	740	405	430	26,420
November	500	390	425	25,269
December	535	365	414	25,478
The year	11,100	210	578	419,107

PECOS RIVER, MARGUERETTA FLUME, AND WEST VALLEY DITCH, NEAR PECOS, TEX.

The summer flow of Pecos River is largely dependent upon numerous springs, which occur in the limestone country in the vicinity of Roswell and below. Owing to the numerous diversions for irrigating purposes, however, the river would be dry in the summer where it crosses into Texas were it not for the waters which are gradually returning to the river through seepage. This water, unfortunately, is impregnated to a considerable extent with alkali, which renders it undesirable for irrigating purposes.

The station on the Pecos River was established January 1, 1898, by Thomas U. Taylor, and is located about 6 miles above Pecos, Tex., at the flume of the Margueretta Canal Company. This canal diverts the water from the Pecos River 3 miles above the flume from the west side of the river. The main canal flows for 3 miles on the west side of the river and then is taken by the flume across the Pecos River to the east side. However, before it reaches the flume the West Valley canal is taken out of the main canal and is made to carry water to the alfalfa farms on the west side of the river. The gage consists of a graduated strip of wood attached to one of the vertical bents of the flume on the upper side of the same. The bench mark is on the top of the west abutment or pier on the north side, and its elevation is

feet above the datum of the gage. The channel at this point is straight, the water at low stages rather sluggish, the banks and the bottom sandy. The gage heights on the flume are ned by measuring the depths of the water in the flume at the end. The zero of this gage is at the bottom of the flume. The of the river have no connection with each other except that they eographically at the same place on the river and have the same ver, Willard H. Dennis, who reads both gages. For the years and 1902 Mr. Dennis has also taken the measurements of the flow e Pecos, the flume, and the ditch at this station. The measure- s are made above the flume by wading, a wire being stretched s the river and tagged every 4 feet. A full description of the s and ditches in this section is given on page 62 of Water-Supply r No. 13.

Discharge measurements of Pecos River and Margueretta flume near Pecos, Tex.

Date.	Gage height Pecos River.	Pecos River discharge.	Margueretta flume discharge.
1902.	*Feet.*	*Second-feet.*	*Second-feet.*
ıber 29	2.00	119	.....
r 3	2.00	109	115
r 6	2.40	153	106
r 10	2.20	132	117
r 14	2.00	103	132
r 18	2.10	127	123
r 21	2.15	120	126
r 24	2.00	107	.....
r 27	2.30	162	130
ber 3	1.90	97	126
ber 3	3.60	390	82
ber 4	3.30	306	87
ber 6	2.80	221	99

Discharge of West Valley ditch near Pecos, Tex.

Date.	Discharge.	Date.	Discharge.	Date.	Dis char
1902.	*Sec.-feet.*	1902.	*Sec.-feet.*	1902.	*Sec.-*
March 24	10	June 16	16	October 6	
March 31	10	June 23	14	October 10	
April 8	10	June 29	14	October 13	
April 14	14	July 6	10	October 14	
April 21	16	August 24	16	October 18	
April 28	14	August 31	10	October 19	
May 5	16	September 7	16	October 21	
May 12	14	September 14	16	October 26	
May 18	16	September 21	14	October 27	
May 26	16	September 28	14	November 2	
June 2	18	October 3	14	November 3	
June 9	14	October 5	9		

Daily gage height, in feet, of Pecos River near Pecos, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1	4.90	2.80	2.60	0.90	0.40	0.50	1.10	4.45	2.00	2.00	1.90	
2	5.10	2.80	2.70	.90	.40	.50	1.10	3.85	2.00	2.00	1.95	
3	5.00	2.70	2.70	.85	.40	.50	1.10	3.65	2.00	2.10	2.00	
4	5.00	3.30	2.70	.85	.40	.50	2.00	3.55	2.00	2.10	2.00	
5	4.95	3.50	2.65	.85	.40	.50	1.65	3.20	3.15	2.30	2.00	
6	5.00	3.50	2.60	.90	.40	.50	1.35	3.05	3.30	2.45	2.00	
7	4.90	3.55	2.55	.90	.40	3.65	1.10	4.00	2.90	2.20	2.00	
8	4.30	3.55	2.45	.80	.40	3.55	1.10	4.20	2.75	2.10	2.00	
9	4.00	3.50	2.40	.65	.40	4.75	1.10	3.55	3.15	2.10	2.05	
10	3.95	3.45	2.40	.55	.40	6.50	1.75	4.00	3.35	2.15	2.10	
11	3.85	2.95	2.35	.50	.40	5.25	5.30	5.05	3.15	2.15	2.10	
12	3.45	3.00	2.30	.50	.40	3.10	9.50	7.65	3.10	2.10	2.10	
13	3.15	3.70	2.30	.50	.50	1.95	12.00	5.15	2.90	2.10	2.10	
14	3.00	4.05	2.30	.50	.55	1.50	7.70	4.25	2.80	2.05	2.00	
15	2.95	4.05	2.25	.50	.65	1.15	6.00	3.75	2.45	2.10	2.00	
16	2.90	3.90	2.20	.50	.80	1.05	5.10	3.55	2.10	2.10	2.00	
17	2.80	3.90	2.20	.40	.70	1.00	4.55	3.40	2.05	2.10	2.00	
18	2.80	3.80	2.05	.40	.70	5.50	3.95	3.35	2.00	2.10	2.00	
19	2.80	3.45	1.85	.40	.70	6.55	3.85	3.25	2.05	2.25	2.00	
20	2.75	3.10	1.65	.40	.65	3.70	6.45	3.05	2.10	2.30	2.00	
21	2.70	3.10	1.50	.40	.50	2.85	8.70	2.90	2.45	2.10	2.00	
22	2.70	3.05	1.50	.40	.50	2.50	8.50	2.70	2.50	2.10	2.00	
23	2.70	2.95	1.50	.40	.50	1.75	11.70	2.55	2.40	2.10	2.00	
24	2.70	2.90	1.55	.40	.50	1.50	13.90	2.50	2.60	2.00	2.10	
25	2.70	2.85	1.50	.40	.50	1.30	12.35	2.50	2.70	2.30	2.15	
26	2.70	2.80	1.50	.40	.50	1.15	9.40	2.35	2.60	2.30	2.00	
27	2.70	2.70	1.50	.40	.50	1.10	7.95	2.30	2.40	2.30	2.00	
28	2.70	2.60	1.40	.40	.50	1.10	7.70	2.20	2.15	2.30	2.00	
29	2.70	.....	1.30	.40	.50	1.10	7.35	2.15	2.00	2.15	2.15	
30	2.70	.....	1.25	.40	.50	1.10	6.85	2.05	2.00	2.05	2.40	
31	2.70	.....	1.05	.....	.50	.....	5.90	2.00	.....	2.00	.....	

Daily gage height, in feet, of Margueretta flume near Pecos, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.95	2.52	2.50	2.00	1.75	1.85	1.90	0.00	2.30	2.15	2.20	2.15
2	3.00	2.50	2.50	1.95	1.85	1.95	1.75	.00	2.30	2.25	2.30	2.15
3	3.00	2.50	2.60	1.85	2.00	1.50	1.75	.60	2.30	2.35	2.25	1.95
4	3.00	2.65	2.60	1.85	1.85	1.45	2.05	1.25	2.15	2.20	2.30	2.05
5	3.05	2.60	2.60	1.60	1.70	1.62	2.20	1.55	1.60	2.40	2.35	2.15
6	3.10	2.55	2.60	1.60	1.65	1.65	1.65	1.90	3.00	2.30	2.30	2.10
7	3.00	2.55	2.60	1.55	1.70	2.50	1.30	2.30	1.85	2.00	2.30	2.05
8	2.78	2.55	2.58	1.50	1.70	2.50	1.30	2.85	1.10	2.00	2.30	2.10
9	2.85	1.40	2.55	1.50	1.70	2.55	1.95	.85	1.25	2.10	2.25	2.15
10	2.85	1.40	2.60	1.40	1.55	1.75	1.80	.95	1.35	2.10	2.20	2.20
11	2.85	1.25	2.52	1.65	1.50	1.95	1.45	3.00	1.15	2.05	2.20	2.20
12	2.75	1.35	2.42	2.10	1.60	2.30	1.90	.....	1.50	2.05	2.20	2.20
13	2.80	1.72	2.50	2.25	1.60	2.32	3.20	3.00	1.40	2.10	2.20	2.20
14	2.78	2.60	2.45	2.20	1.60	2.32	2.50	3.00	80	2.10	2.15	2.20
15	2.78	2.50	2.25	2.00	1.75	1.78	1.10	2.90	1.00	2.10	2.15	2.30
16	2.80	2.40	2.25	1.75	2.10	1.50	.60	2.80	1.70	2.10	2.10	2.25
17	2.80	2.40	2.40	1.75	2.05	1.60	15	2.25	1.70	2.20	2.10	2.20
18	2.90	2.40	2.40	1.80	2.00	2.25	.00	2.25	1.50	2.20	2.10	2.20
19	2.85	2.35	2.40	1.80	1.85	2.40	00	2.15	2.65	2.10	2.10	2.20
20	2.80	2.20	2.35	1.90	1.60	2.50	15	1.65	2.10	2.10	2.10	2.20
21	2.80	2.20	2.48	1.90	1.50	2.45	2.05	2.35	1.80	2.30	2.15	2.20
22	2.85	2.20	2.40	1.70	1.60	2.20	3.10	2.15	1.80	2.30	2.20	2.30
23	2.80	2.20	2.40	1.40	1.60	2.30	3.35	1.60	1.85	2.30	2.20	2.30
24	2.80	2.10	1.85	1.35	1.75	2.20	3.65	1.50	2.10	2.40	2.20	2.30
25	2.75	2.30	1.90	1.45	2.00	2.05	3.50	1.50	2.20	2.45	2.20	2.30
26	2.75	2.40	2.00	1.65	1.95	1.85	3.10	1.50	2.05	2.35	2.20	2.20
27	2.75	2.50	2.00	1.65	1.70	1.75	2.30	1.60	2.10	2.35	2.15	2.30
28	2.75	2.40	2.05	1.75	1.65	1.68	2.50	2.05	2.10	2.40	2.15	2.30
29	2.75	.....	2.10	1.60	1.60	1.65	2.00	2.20	2.10	2.30	2.20	2.30
30	2.75	.....	80	1.65	1.45	1.90	.55	2.25	2.05	2.30	2.00	2.30
31	2.72	.....	1.90	.....	1.55	.....	.00	2.30	.....	2.30	.....	2.30

Rating table for Pecos River near Pecos, Tex., for 1902. [a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.7	77	3.0	240	4.3	574	8.0	2,022
1.8	83	3.1	260	4.4	606	8.5	2,222
1.9	90	3.2	280	4.5	640	9.0	2,422
2.0	98	3.3	302	4.6	674	9.5	2,622
2.1	107	3.4	324	4.7	710	10.0	2,822
2.2	117	3.5	348	4.8	746	10.5	3,022
2.3	128	3.6	372	4.9	784	11.0	3,222
2.4	140	3.7	398	5.0	822	11.5	3,422
2.5	154	3.8	425	5.5	1,022	12.0	3,622
2.6	170	3.9	453	6.0	1,222	12.5	3,822
2.7	186	4.0	482	6.5	1,422	13.0	4,022
2.8	204	4.1	512	7.0	1,622	13.5	4,222
2.9	222	4.2	542	7.5	1,822		

[a] This is made up from measurements of the river only; does not include ditch or flume.

Estimated monthly discharge of Pecos River near Pecos, Tex.

Month.	Discharge in second-feet.			Total acre-fe
	Maximum.	Minimum.	Mean.	
1902.				
January	862	185	381	2:
February	497	170	304	1(
March 1 to 19 [a]			144	:
June 7 to 13 and 18 to 23 [a]			577	1:
July 10 to 31 [a]			1,881	8:
August	1,882	98	383	2:
September	313	98	167	:
October	147	98	112	(
November	140	90	102	(
December	385	170	205	1:

[a] As no discharge measurements have been made at low water, discharges for gage heights than 1.7 feet can not be computed. Gage height of 1.7 feet corresponds to a discharge of 77 se feet. For periods not covered by above table discharges were less than 77 second-feet. See ta gage heights.

RIO GRANDE AT LANGTRY, TEX.

This station was established in April, 1900, by the Internati (Water) Boundary Commission. It is located one-half mile soutl Langtry station, on the Southern Pacific Railway, and is about miles below El Paso, Tex., at the eastern end of the canyon sec of the Rio Grande, and a short distance to the west of the moutl Pecos River, one of the principal tributaries of the Rio Grande.

Discharge measurements of the Rio Grande at Langtry, Tex.

[Made by Jas. P. Hague and J. D. Dillard.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Disch:
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second*
January 3	0.9	806	February 14	0.95	
January 7	.9	684	February 18	1.0	
January 9	.9	592	February 21	.9	
January 12	.9	649	February 25	.9	
January 17	1.0	589	February 28	.9	
January 20	1.0	651	March 3	.8	
January 24	.9	554	March 6	.8	
January 27	1.0	636	March 10	.8	
January 31	.95	563	March 13	.8	
February 3	1.0	571	March 15	.8	
February 7	1.0	563	March 18	.75	
February 11	.95	550	March 21	.75	

Discharge measurements of the Rio Grande at Langtry, Tex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
25	.7	391	August 8	2.95	3,060
27	.7	403	August 13	2.3	2,043
31	.65	370	August 18	3.95	5,066
2	.65	362	August 22	4.0	5,263
5	.65	373	August 26	5.9	9,328
9	.65	361	August 30	5.45	8,268
12	.65	368	September 3	5.15	7,843
17	1.0	591	September 7	7.95	14,979
21	.7	378	September 11	10.65	23,471
24	.65	318	September 20	3.8	4,749
28	.65	304	September 24	3.1	3,261
	.6	283	September 28	2.6	2,360
	1.35	845	September 30	2.7	2,532
	.65	310	October 3	2.75	2,523
2	.6	286	October 7	2.35	1,957
5	1.1	656	October 11	2.8	2,661
8	2.2	1,899	October 15	2.35	2,011
2	.75	362	October 19	2.0	1,540
6	.7	329	October 23	1.8	1,317
1	1.7	1,189	October 27	1.7	1,202
	.75	358	October 31	1.65	1,142
	.7	305	November 4	1.7	1,222
3	1.35	797	November 8	1.8	1,324
7	1.0	501	November 12	1.5	1,032
1	1.8	1,269	November 16	1.4	939
6	.7	316	November 20	1.35	868
	1.9	1,360	November 24	1.35	863
	.85	382	November 28	1.3	815
)	2.95	3,067	December 1	1.3	779
4	5.0	6,696	December 5	1.9	1,434
8	2.35	2,125	December 10	1.35	839
2	3.0	2,997	December 15	1.35	831
6	8.0	12,962	December 20	1.4	893
1	5.45	7,599	December 26	1.35	845
t 4	3.4	3,902			

Daily gage height, in feet, of the Rio Grande at Langtry, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	0.90	0.90	0.90	0.65	0.65	1.00	1.65	4.75	5.90	2.80	2.55	1.3[illegible]
2	.90	1.00	.80	.65	.60	.85	.90	3.80	5.80	3.10	1.95	1.3[illegible]
3	.90	1.00	.80	.65	.60	.80	1.00	3.40	5.45	3.40	2.15	1.6[illegible]
4	.90	1.00	.80	.65	.70	.80	.90	3.25	6.40	3.20	1.95	1.7[illegible]
5	.90	1.00	.80	.65	1.55	.75	.85	2.90	7.00	3.40	2.85	1.6[illegible]
6	.90	1.00	.80	.65	.80	.75	.90	3.70	7.85	2.65	2.55	1.6[illegible]
7	.90	1.00	.80	.65	.65	.70	1.10	3.70	8.10	2.40	2.00	1.6[illegible]
8	.90	1.00	.80	.65	.65	.70	1.20	2.80	10.40	2.20	1.80	1.5[illegible]
9	.90	1.00	.80	.65	.65	.70	2.20	2.65	14.65	2.20	1.65	1.5[illegible]
10	.90	1.00	.80	.65	.65	1.00	3.05	2.50	12.95	2.10	1.55	1.3[illegible]
11	.90	.95	.80	.65	.65	1.35	2.80	2.50	10.65	2.75	1.50	1.3[illegible]
12	.90	.95	.80	.65	.60	1.70	2.90	2.45	10.05	2.70	1.50	1.3[illegible]
13	.90	.95	.80	2.95	.60	1.40	7.00	4.65	8.85	2.60	1.45	1.3[illegible]
14	1.10	.95	.80	1.00	.75	1.25	4.80	6.25	7.25	2.55	1.45	1.3[illegible]
15	1.10	.95	.80	2.15	1.10	1.20	3.90	5.65	6.40	2.30	1.40	1.3[illegible]
16	1.10	.90	.80	2.05	.95	1.10	3.50	5.25	5.70	2.20	1.40	1.4[illegible]
17	1.00	.90	.80	1.40	.80	1.10	2.55	4.40	5.05	2.15	1.40	1.4[illegible]
18	1.00	1.00	.75	.80	2.45	1.45	2.45	3.95	4.35	2.05	1.40	1.4[illegible]
19	1.00	.90	.75	.80	1.15	1.80	2.95	3.95	4.05	2.00	1.40	1.4[illegible]
20	1.00	.90	.75	.80	.85	1.80	2.60	4.05	3.95	1.95	1.40	1.4[illegible]
21	1.00	.90	.75	.80	.80	1.80	3.20	3.95	6.25	1.90	1.35	1.4[illegible]
22	1.00	.90	.75	.75	.75	1.10	2.90	3.90	5.05	1.85	1.35	1.4[illegible]
23	1.00	.90	.70	.70	.75	1.00	4.35	3.75	3.55	1.80	1.35	1.4[illegible]
24	.95	.90	.70	.65	1.30	.85	4.00	4.45	3.05	1.80	1.35	1.4[illegible]
25	.90	.90	.70	.65	.80	.75	10.45	5.10	2.95	1.75	1.40	1.4[illegible]
26	.95	.90	.70	.65	.75	.70	7.60	5.90	2.90	1.75	1.70	1.4[illegible]
27	1.00	.90	.70	.65	.75	.70	7.45	5.15	2.75	1.70	1.40	1.4[illegible]
28	1.00	.90	.70	.65	.75	.70	7.75	4.60	2.65	1.70	1.30	1.35
29	1.00	.....	.70	.65	1.60	.70	8.10	4.55	2.70	1.70	1.30	1.35
30	1.00	.....	.65	.65	1.60	4.10	5.80	5.60	2.70	1.65	1.30	1.35
31	.90	.....	.65	.....	1.60	.....	5.45	6.40	.....	1.60	.....	1.35

Estimated monthly discharge of the Rio Grande at Langtry, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	820	550	663	40,760
February	580	510	542	30,089
March	530	370	435	26,717
April	3,380	305	611	36,367
May	2,250	285	544	33,451
June	5,170	305	745	44,301
July	20,800	380	4,964	305,216
August	10,550	2,250	5,672	348,734
September	38,200	2,440	11,160	664,046
October	3,900	1,080	1,948	119,782
November	2,740	815	1,190	70,800
December	1,330	780	917	56,370
The year	38,200	285	2,449	1,776,633

RIO GRANDE BELOW PRESIDIO, TEX.

is station was established April 8, 1900, by the International er) Boundary Commission. It is 6 miles below Presidio, also r the mouth of Conchos River, and about 215 miles below El Paso. at the western end of the canyon section of the Rio Grande. lischarge at this station, minus the discharge at the station above dio, Tex., gives the discharge of the Conchos, except at rare inter- when some rain water enters the Rio Grande from the north.

Discharge measurements of the Rio Grande below Presidio, Tex. [a]

[Made by S. D. Church and J. P. Hague.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
.3	4.2	98	June 11	4.7	26
6	4.2	85	June 13	5.2	74
10	4.1	77	June 16	4.7	30
12	4.0	58	June 20	4.5	15
14	3.9	52	July 2	8.55	2,275
17	3.9	51	July 4	5.0	170
19	3.9	48	July 7	7.3	517
21	3.8	41	July 9	8.9	3,086
24	3.8	35	July 14	8.05	2,156
26	3.7	30	July 16	8.2	2,265
28	3.7	32	July 18	7.65	1,473
2	3.7	32	July 21	9.4	4,883
4	3.7	32	July 22	11.0	9,539
7	3.7	29	July 24	12.15	13,706
9	3.6	26	July 26	12.2	14,352
11	3.6	25	July 28	11.4	10,579
14	3.6	22	July 30	9.6	5,313
16	3.6	23	August 1	8.9	3,601
18	3.6	22	August 4	7.6	1,854
21	3.5	20	August 6	8.3	1,909
23	3.5	21	August 8	7.7	1,528
25	3.5	20	August 10	8.3	1,794
	3.4	13	August 12	10.8	7,030
	3.4	12	August 14	10.2	5,999
	3.4	11	August 16	10.25	6,082
2	3.4	10	August 18	9.75	4,971
0	3.5	8	August 20	9.85	5,426
	3.9	7	August 22	9.8	5,416
	6.85	405	August 24	11.3	8,831

o measurements for January and February, 1902. Daily flow computed from gage record.

Discharge measurements of the Rio Grande below Presidio, Tex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Disch
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second*
August 26	10.0	5,776	October 20	6.2	
August 28	11.4	10,361	October 23	6.05	
August 30	11.45	10,522	October 25	6.0	
September 1	10.15	5,781	October 27	5.8	
September 4	12.85	15,932	October 30	6.05	
September 8	16.75	32,962	November 1	5.7	
September 9	13.7	23,771	November 4	5.65	
September 11	12.5	17,686	November 7	5.4	
September 15	10.5	7,169	November 10	5.4	
September 17	8.3	3,669	November 13	5.2	
September 19	8.2	3,396	November 16	5.15	
September 20	7.7	2,652	November 19	5.1	
September 22	7.5	2,125	November 22	5.05	
September 24	7.5	2,125	November 25	5.0	
September 25	7.5	2,157	November 28	5.0	
September 27	7.3	1,933	December 1	6.5	
September 29	7.15	1,742	December 6	5.4	
October 1	7.1	1,617	December 9	5.2	
October 3	6.85	1,438	December 12	5.2	
October 6	6.65	1,245	December 15	5.35	
October 8	7.6	2,230	December 18	5.3	
October 10	7.2	1,963	December 21	5.25	
October 13	6.8	1,758	December 24	5.05	
October 15	6.6	1,080	December 27	5.05	
October 17	6.4	1,010	December 30	5.05	

Daily gage height, in feet, of the Rio Grande below Presidio, Tex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.											
1	5.00	4.80	4.20	3.70	3.45	3.90	4.75	8.70	10.60	7.10	5.80
2	4.95	4.75	4.20	3.70	3.40	3.90	8.15	8.20	10.20	8.15	6.65
3	4.90	4.65	4.20	3.70	3.40	3.90	5.50	7.90	11.10	6.85	7.25
4	4.80	4.60	4.20	3.70	3.40	3.90	5.00	7.65	12.85	6.80	5.80
5	4.90	4.60	4.20	3.70	3.40	3.90	5.00	7.70	14.25	6.80	5.65
6	5.15	4.60	4.20	3.70	3.40	3.90	6.60	8.45	16.50	6.65	5.50
7	5.40	4.70	4.20	3.70	3.40	3.90	7.45	7.55	17.95	7.45	5.45
8	5.35	4.65	4.15	3.70	3.40	5.60	8.40	7.70	16.65	7.65	5.40
9	5.25	4.55	4.0	3.60	3.40	7.40	9.10	7.50	14.00	7.45	5.40
10	5.15	4.45	4.10	3.60	3.40	5.30	11.60	8.40	12.90	7.25	5.40
11	5.10	4.40	4.10	3.60	3.40	4.70	12.20	11.50	12.65	7.10	5.30
12	5.10	[illegible]40	4.00	3.60	3.40	4.70	10.30	11.40	12.45	6.90	5.30
13	5.10	4.35	3.90	3.60	3.40	5.20	9.15	10.40	12.15	6.80	5.15
14	5.00	4.30	3.90	3.60	4.35	5.10	8.05	10.30	11.05	6.70	5.20

Daily gage height, in feet, of the Rio Grande below Presidio, Tex.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
15	5.00	4.30	3.90	3.60	3.80	4.85	7.70	10.10	10.55	6.60	5.20	5.35
16	4.90	4.30	3.90	3.60	3.60	4.70	8.20	10.20	9.35	6.50	5.15	5.40
17	4.80	4.30	3.90	3.60	3.60	4.80	7.80	9.70	8.50	6.40	5.10	5.30
18	4.90	4.30	3.90	3.60	3.50	4.55	7.65	9.90	8.30	6.30	5.10	5.30
19	5.15	4.30	3.90	3.50	3.50	4.55	7.40	9.90	8.15	6.20	5.10	5.30
20	5.15	4.30	3.90	3.50	3.50	4.90	9.80	9.85	7.75	6.20	5.10	5.20
21	5.00	4.30	3.80	3.50	3.50	4.40	9.40	10.00	7.60	6.20	5.10	5.25
22	5.00	4.25	3.80	3.50	3.50	4.40	12.25	9.95	7.50	6.10	5.05	5.10
23	4.90	4.20	3.80	3.50	3.50	4.40	12.60	10.80	7.60	6.05	5.00	5.10
24	4.80	4.20	3.80	3.50	3.50	4.40	12.10	11.40	7.50	6.00	5.00	5.05
25	5.10	4.20	3.80	3.50	5.55	4.40	12.10	11.40	7.45	6.00	5.00	5.05
26	5.30	4.20	3.70	3.50	4.00	4.40	12.75	10.20	7.50	5.90	5.00	5.05
27	5.30	4.20	3.70	3.50	3.90	4.40	12.00	10.80	7.35	5.80	5.00	5.05
28	5.20	4.20	3.70	3.50	3.90	4.40	11.50	11.50	7.25	5.80	5.00	5.05
29	5.15		3.70	3.50	3.90	4.30	10.50	11.55	7.15	5.80	5.00	5.05
30	5.00		3.70	3.50	3.90	4.30	9.60	11.40	7.10	6.00	5.00	5.05
31	4.90		3.70	.....	3.90	.....	8.95	11.30	.....	5.85	.....	5.00

Estimated monthly discharge of the Rio Grande below Presidio, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	350	220	259	15,907
February	220	100	141	7,835
March	100	30	59	3,610
April	30	20	24	1,448
May	15	10	11	674
June	625	10	48	2,866
July	17,100	40	5,918	363,888
August	10,900	1,300	5,702	350,618
September	45,000	1,680	10,755	639,947
October	3,320	720	1,305	80,212
November	2,000	415	590	35,098
December	1,070	380	493	30,317
The year	45,000	10	2,109	1,532,420

RIO GRANDE ABOVE PRESIDIO, TEX.

This station was established April 4, 1900, by the International (Water) Boundary Commission. It is 7 miles above Presidio and above the mouth of Conchos River, one of the principal tributaries of the Rio Grande, and is about 200 miles below El Paso. Its location is far enough above the mouth of Conchos River to be free from the effects of backwater from that stream.

Discharge measurements of the Rio Grande above Presidio, Tex.[a]

[Made by J. P. Hague.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discha
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-*
July 5	1.4	53	August 11	5.5	1
July 10	4.0	857	August 13	2.65	
July 12	4.1	943	August 15	2.4	
July 15	2.55	289	September 2	2.0	
July 17	1.95	143	September 5	3.45	
July 19	1.55	61	September 8	2.1	
July 23	7.3	2,683	September 10	2.0	
July 25	5.6	1,326	October 12	.7	
July 29	2.15	193	November 3	1.5	
July 31	1.75	62	November 5	1.0	
August 2	.9	14	November 8	.8	

[a] No measurements made at this station during January, February, and December, 1902. Daily flow computed from gage record. River was dry during May and June, 1902.

Daily gage height, in feet, of the Rio Grande above Presidio, Tex.

Day.	Jan.	Feb.	Mar.	Apr	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.											
1	1.20	1.30						1.60	3.55		0.90
2	1.20	1.30					3.05	0.95	3.55		3.55
3	1.10	1.25					0.75		4.85		1.75
4	1.00	1.20					1.95		4.95		1.20
5	1.10	1.20				1.20	1.40		3.40	1.65	1.00
6	1.35	1.30							4.35	0.75	0.90
7	1.60	1.40							3.65		1.05
8	1.50	1.40				0.55			2.15		0.85
9	1.50	1.30							2.00		0.25
10	1.40	1.25					4.05	1.20	1.90		
11	1.40	1.20					6.45	5.50	0.80		
12	1.40	1.10					3.90	5.20		0.60	
13	1.40	0.90					2.75	2.50			
14	1.30	0.70					2.30	3.10			
15	1.30	0.50					2.55	2.20			
16	1.20	0.30					2.15	1.15			
17	1.10	([a])					1.85				
18	1.30						1.50				
19	1.50						1.50				
20	1.50						3.20				
21	1.40						5.25				
22	1.40						4.80				
23	1.30						7.40				
24	1.20						6.55				
25	1.50						5.70				
26	1.65						3.70				
27	1.70						2.80				
28	1.60						2.60				
29	1.60						2.30				
30	1.50						2.25				
31	1.40						1.75				

[a] On days for [illegible] here are no gage heights the river was dry.

Estimated monthly discharge of the Rio Grande River above Presidio, Tex.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	130	40	77	4,741
February	70	0	29	1,607
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	60	0	3	159
July	2,740	0	568	34,929
August	1,250	0	102	6,288
September	1,080	0	205	12,198
October	70	0	3	198
November	670	0	28	1,676
December	240	0	8	496
The year	2,740	0	85	62,292

RIO GRANDE NEAR FORT HANCOCK, TEX.

This station was established by the International (Water) Boundary Commission March 27, 1900. It is 1½ miles southeast of Fort Hancock, on the Southern Pacific Railway, in the El Paso Valley, and is about 55 miles below El Paso.

Discharge measurements of the Rio Grande near Fort Hancock, Tex.[a]

[Made by A. L. Wilcox and F. W. Carpenter.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
July 21	2.5	6	September 4	4.5	249
July 23	3.0	18	September 6	3.4	81
July 24	2.4	5	September 9	3.2	72
August 30	6.3	808	September 12	2.1	8
September 1	7.0	1,034	October 7	2.5	16

[a] No measurements made at this station during months of January and February.

Daily flow computed from gage heights.
River was dry during March, April, May, and June, 1902.
No measurements were made at this station during November and December, 1902. River was dry.

Daily gage height, in feet, of the Rio Grande near Fort Hancock, Tex.[a]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	4.80	5.30	.....	.....	.....	.....	.....	.....	6.90	3.35	.....	.....
2	4.90	5.50	.....	.....	.....	.....	.....	.....	5.85	3.05	.....	.....
3	5.00	5.60	.....	.....	.....	.....	.....	.....	5.20	2.70	.....	.....
4	5.10	5.50	.....	.....	.....	.....	.....	.....	4.60	3.65	.....	.....
5	5.10	5.40	.....	.....	.....	.....	.....	.....	4.00	3.90	.....	.....
6	5.10	5.30	.....	.....	.....	.....	.....	.....	3.35	2.90	.....	.....
7	5.20	5.30	.....	.....	.....	.....	.....	.....	3.30	2.35	.....	.....
8	5.30	5.20	.....	.....	.....	.....	.....	.....	3.20	2.00	.....	.....
9	5.30	5.10	.....	.....	.....	.....	.....	.....	3.15	.....	.....	.....
10	5.40	5.20	.....	.....	.....	.....	.....	.....	2.75	.....	.....	.....
11	5.50	5.20	.....	.....	.....	.....	.....	.....	2.40	.....	.....	.....
12	5.50	5.20	.....	.....	.....	.....	.....	.....	2.10	.....	.....	.....
13	5.60	5.30	.....	.....	.....	.....	4.30	.....	2.00	.....	.....	.....
14	5.70	5.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	5.70	5.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	5.80	5.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	5.80	4.95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	5.70	4.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	5.70	4.55	.....	.....	.....	.....	.....	.....	2.45	.....	.....	.....
20	5.50	4.35	.....	.....	.....	.....	5.40	.....	2.40	.....	.....	.....
21	5.80	4.00	.....	.....	.....	.....	2.15	.....	2.10	.....	.....	.....
22	5.75	3.75	.....	.....	.....	.....	4.40	.....	.....	.....	.....	.....
23	5.80	.....	.....	.....	.....	.....	3.50	.....	.....	.....	.....	.....
24	5.70	.....	.....	.....	.....	.....	2.40	.....	.....	.....	.....	.....
25	5.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	5.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	5.60	.....	.....	.....	.....	.....	3.40	.....	.....	.....	.....	.....
28	5.60	.....	.....	.....	.....	.....	2.60	.....	.....	.....	.....	.....
29	5.60	.....	.....	.....	.....	.....	.....	.....	5.15	.....	.....	.....
30	5.50	.....	.....	.....	.....	.....	.....	5.00	4.05	.....	.....	.....
31	5.40	.....	.....	.....	.....	.....	.....	7.30	.....	.....	.....	.....

[a] On the days for which no gage heights are given the river was dry.

Estimated monthly discharge of the Rio Grande near Fort Hancock, Tex.[a]

Month.[a]	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	160	40	112	6,883
February	120	0	57	3,154
July	460	0	26	1,587
August 30 and 31	1,090	0	47	2,916
September	1,000	0	122	7,240
October	165	0	17	1,061
The year	1,090	0	32	22,841

[a] For the months for which no figures are given the river was dry.

RIO GRANDE NEAR EL PASO, TEX.

This station was located at the pumping house of the smelter company, 3 miles north of El Paso, Tex. The bed of the stream here is composed of mud, constantly shifting and changing. May 1, 1897, the station was placed under the charge of W. W. Follett, consulting engineer, International (Water) Boundary Commission, and by him removed 1 mile farther up the river to Courchesne's limekiln. The river heights were measured at the masonry pump foundation pier, 150 feet above the kiln. The top of the downstream chisel draft on this pier was assumed to be at a gage height of 15.0 feet, and the distance of the surface of the water below it was measured with a carefully graduated rod. This pier was torn down in October, 1902, and an inclined wooden gage established some 60 feet upstream. This is a 2 by 4 bolted to 1¼-inch steel bars set with cement in holes drilled in solid rock. The graduations are notches cut in the scantling. The B. M. is a one-half-inch iron bolt set in solid rock at the head of the gage. Its top is 13.00 feet above gage datum. The left bank of the river is formed by the loose rock fill of the Atchison, Topeka and Santa Fe Railroad embankment, and will not overflow. The right bank, however, is not so good, being made ground and subject to overflow. The bottom of the river here has also proven unstable, scouring on a rise and filling on a falling river. It is probably the best site for a station in the vicinity of El Paso, however, as the entire river bed is constantly shifting for many miles above and below. On account of this shifting character of the stream, the only accurate method of estimating the daily discharges is by taking a large number of measurements, which was done in 1902 by T. M. Courchesne, J. P. Hague, A. L. Wilcox, F. W. Carpenter, and I. H. Huggett.

Discharge measurements of the Rio Grande near El Paso, Tex. [a]

[Made by T. M. Courchesne, Jas. P. Hague, A. L. Wilcox, and F. W. Carpenter, and I. H. Huggett.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
January 30	6.3	145	May 2	5.85	64
February 1	6.4	165	May 5	5.4	19
April 18	6.75	262	May 7	5.2	5
April 21	7.0	301	June 3	6.05	134
April 22	6.6	195	June 4 [b]	5.4	17
April 24	6.6	200	August 27	9.0	1,578
April 26	7.3	465	August 28	6.3	937
April 28	7.3	441	August 29	9.8	2,050
April 30	6.3	145	August 31	9.0	1,190

[a] No measurement for March. Water too shallow.
[b] River dry the remainder of month, throughout July, and until August 27.

Discharge measurements of the Rio Grande near El Paso, Tex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
September 2	7.5	645	October 4	5.6	52
September 5	6.2	160	October 6	5.5	47
September 8	5.6	73	October 8	5.35	37
September 10	5.4	23	October 10	5.3	29
September 13	5.1	5	October 15	4.9	8
September 27	7.9	653	October 17	4.85	4
September 28	7.1	369	December 22	5.9	117
September 30	6.4	171	December 24	5.6	80
October 2	6.0	101	December 26	5.2	34
October 3	5.9	85	December 29	4.7	4

No measurements for November.

Daily gage height, in feet, of the Rio Grande near El Paso, Tex.[a]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	6.30	6.40	4.90	4.90	5.90	.....	.....	.....	8.10	6.15	.....	5.30
2	6.30	6.40	4.90	4.90	5.80	.....	.....	.....	7.50	6.00	.....	5.30
3	6.30	6.30	4.90	4.90	5.75	6.05	.....	.....	7.00	5.95	.....	5.25
4	6.30	6.30	4.90	4.90	5.45	5.25	.....	.....	6.40	5.65	.....	5.20
5	6.30	6.30	4.90	4.90	5.35	5.00	.....	.....	6.20	5.50	.....	5.20
6	6.30	6.20	4.90	4.90	5.20	.....	.....	.....	6.00	5.45	.....	5.10
7	6.30	6.20	4.90	4.90	5.20	.....	.....	.....	5.80	5.40	.....	5.35
8	6.30	6.20	4.90	4.90	5.20	.....	.....	.....	5.60	5.40	.....	5.25
9	6.30	6.10	4.90	4.90	5.20	.....	.....	.....	5.50	5.35	.....	5.20
10	6.30	6.00	4.90	4.90	5.20	.....	.....	.....	5.40	5.30	.....	5.10
11	6.30	6.00	4.90	4.90	5.20	.....	.....	.....	5.30	5.30	.....	5.00
12	6.30	6.00	4.90	4.90	5.10	.....	5.05	.....	5.20	5.20	.....	4.90
13	6.30	6.00	4.90	4.90	.....	.....	.....	.....	5.10	5.20	.....	4.75
14	6.30	6.05	4.90	4.90	.....	.....	.....	.....	.....	5.15	.....	4.70
15	6.30	6.20	4.90	4.90	.....	.....	.....	.....	.....	4.95	.....	4.70
16	6.30	6.30	4.90	4.90	.....	.....	.....	.....	.....	4.90	.....	.....
17	6.30	6.25	4.90	4.90	.....	.....	.....	.....	.....	4.90	.....	.....
18	6.30	6.20	4.90	6.80	.....	.....	.....	.....	.....	4.90	.....	.....
19	6.30	6.20	4.90	6.90	.....	.....	.....	.....	.....	.....	.....	.....
20	6.30	6.20	4.90	6.90	.....	.....	.....	.....	.....	.....	.....	.....
21	6.30	6.10	4.90	6.95	.....	.....	.....	.....	.....	.....	.....	5.30
22	6.30	5.95	4.90	6.65	.....	.....	.....	.....	.....	.....	.....	5.90
23	6.30	5.75	4.90	6.60	.....	.....	.....	.....	.....	.....	.....	5.65
24	6.30	5.50	4.90	6.55	.....	.....	.....	.....	.....	.....	.....	5.45
25	6.30	5.30	4.90	6.80	.....	.....	.....	.....	.....	.....	.....	5.35
26	6.30	5.05	4.90	7.30	.....	.....	.....	.....	7.60	.....	5.30	5.15
27	6.30	5.00	4.90	7.50	.....	.....	.....	6.30	7.85	.....	5.30	5.05
28	6.30	5.00	4.90	7.25	.....	.....	.....	7.75	7.10	.....	5.30	4.95
29	6.30	.....	4.90	6.70	.....	.....	.....	9.95	6.55	.....	5.30	4.75
30	6.30	.....	4.90	6.30	.....	.....	.....	9.40	6.35	.....	5.30	4.70
31	6.30	.....	4.90	.....	.....	.....	.....	9.05	.....	.....	.....	4.70

[a] On the days for which no gage heights are given the river was dry.

Estimated monthly discharge of the Rio Grande near El Paso, Tex.

[Drainage area, 30,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	140	130	135	8,291	0.0045	0.0052
February	160	30	104	5,772	.0035	.0036
March	20	10	10	635	.0003	.0003
April	540	10	133	7,904	.0044	.0049
May	75	0	9	526	.0003	.0003
June	135	0	5	307	.0002	.0002
July	10	0	0	20	.0000	.0000
August	2,140	0	236	14,499	.0079	.0091
September	860	0	156	9,313	.0052	.0058
October	115	0	23	1,428	.0008	.0009
November	30	0	5	298	.0002	.0002
December	115	0	29	1,775	.0010	.0012
The year	2,140	0	70	50,768	.0024	.0317

RIO GRANDE NEAR SAN MARCIAL, N. MEX.

This station is located about one-half mile south of San Marcial, N. Mex., at the bridge of the Atchison, Topeka and Santa Fe Railroad. The original gage was established by Arthur P. Davis on January 29, 1895. The observer was Bert Halseth, San Marcial, N. Mex., whose house is about one-half mile distant. The gage was of hard pine timber, 9 by 5 inches by 25 feet, anchored and bolted to the east end of the second pier from the south. It was inclined and painted white. The distance between the footmarks was 1.6 feet. The 13-foot mark was level with the extension of the pier, to which the gage was anchored. The 15-foot mark was level with the top of the capstone on which the bridge truss rests. Measurements were made from the same bridge. On August 8, 1889, a station was established near San Marcial, and a measurement was made which gave a discharge of 19 second-feet. Soon after this date, however, the river gage was destroyed and the locality was abandoned until 1895.

In 1896 the inclined gage was carried away and a wire gage was put in its place. The wire gage is attached to the guard rail of the bridge, south span, lower side. Bench mark No. 1 is the top of the capstone on which the bridge truss rests, and is at an elevation of 15 feet above gage datum; bench mark No. 2 is the top of the extension of the pier to which the old vertical gage was fastened, and is at an elevation of 13 feet above gage datum. The wire gage has been abandoned and the gage heights are now measured with a graduated rod from the deck of th bridge but using the old gage datum. The channel is

sandy and shifting. A number of bridge piers interfere with the c rent to a certain extent, but not with the observed gage heights. T sometimes affect the discharge measurements.

Discharge measurements of the Rio Grande near San Marcial, N. Mex.

[Made by W. W. Sentman and J. R. Nisbet.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discha
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-*
January 1	7.2	389	April 24	8.3	1
January 3	7.15	348	April 26	7.9	
January 6	7.3	469	April 28	7.7	
January 27	7.4	238	April 30	7.9	
January 30	7.3	291	May 2	7.7	
February 3	7.4	383	May 8	7.4	
February 5	7.4	425	May 10	7.5	
February 7	7.45	331	May 12	7.6	
February 10	7.6	340	May 14	7.7	
February 12	7.4	358	May 16	8.1	
February 14	7.4	266	May 20	7.8	
February 17	7.5	296	May 22	7.5	
February 20	7.4	279	May 24	7.4	
February 22	7.4	294	May 26	7.1	
February 24	7.4	298	May 28	6.6	
February 28	7.4	222	May 29	8.2	1
March 4	7.3	218	May 31	7.7	
March 6	7.3	195	June 3	7.4	
March 8	7.3	178	June 5	7.4	
March 10	7.1	157	June 7	7.2	
March 12	6.9	84	June 9	7.1	
March 15	6.5	49	June 12 [a]	6.7	
March 17	6.8	88	August 12	7.35	
March 19	7.1	132	August 14	6.9	
March 21	7.0	84	August 16	7.5	
March 27	7.1	113	August 18	7.25	
March 29	7.2	113	August 27	8.25	2
March 31	7.1	115	August 31	6.6	
April 2	7.0	99	September 2	6.5	
April 4	6.9	69	September 4	5.4	
April 7	6.4	23	September 6	5.0	
April 9	5.8	2	September 23	8.4	2
April 12	8.1	841	September 26	6.3	
April 14	8.3	1,275	September 28	5.9	
April 16	8.3	1,307	October 3	5.2	
April 18	8.3	1,157	October 6	4.9	
April 22	8.2	912	October 9	5.0	

[a] River dry the [illegible] he month and during July.

rge measurements of the Rio Grande near San Marcial, N. Mex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
12	4.9	14	November 30	6.0	156
15	4.8	7	December 3	6.0	104
30	4.9	12	December 6	6.1	134
er 2	5.0	13	December 9	6.2	142
er 4	5.0	18	December 14	6.3	151
er 7	5.1	17	December 17	6.7	244
er 10	5.1	18	December 20	6.3	80
er 13	5.2	31	December 22	5.9	60
er 16	6.4	202	December 25	6.5	289
er 20	6.0	117	December 28	6.4	258
er 24	5.9	122	December 31	6.25	186
er 28	5.95	158			

Daily gage height, in feet, of the Rio Grande near San Marcial, N. Mex.[a]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
	7.25	7.35	7.35	7.10	7.80	7.50			6.35	5.35	5.00	6.00
	7.15	7.30	7.50	7.00	7.65	7.40			6.40	5.70	5.00	6.00
	7.25	7.35	7.45	6.90	7.60	7.35			5.70	5.25	5.00	6.00
	7.35	7.45	7.35	6.85	7.55	7.40			5.45	5.05	5.00	5.60
	7.35	7.40	7.35	6.70	7.35	7.40			5.15	5.00	5.00	5.70
	7.30	7.50	7.30	6.55	7.45	7.30			5.05	4.90	5.00	6.15
	7.30	7.45	7.30	6.40	7.40	7.20				4.80	5.10	6.15
	7.30	7.55	7.30	6.20	7.40	7.20				5.15	5.10	6.15
	7.15	7.50	7.20	5.80	7.65	7.15				5.10	5.10	6.20
	7.05	7.60	7.20		7.55	7.05				5.00	5.10	6.25
	7.10	7.40	7.05		7.50	6.85				4.95	5.10	6.30
	7.10	7.45	6.90	8.20	7.60	6.70		7.00		4.90	5.10	6.30
	7.35	7.35	6.80	8.20	7.70	6.55		7.05		4.90	5.20	6.30
	7.40	7.40	6.70	8.35	7.70			7.80		4.90	5.20	6.30
	7.40	7.40	6.50	8.35	7.75			8.50		4.80	5.80	6.50
	7.35	7.50	6.50	8.40	8.50			7.55		4.80	6.30	6.90
	7.40	7.50	6.95	8.25	8.05			7.25			6.20	6.70
	7.40	7.55	7.10	8.30	7.80			7.20			6.05	6.60
	7.30	7.50	7.20	8.00	7.80			6.90			6.00	6.40
	7.35	7.45	7.20	8.15	7.75			6.65			6.00	6.30
	7.30	7.35	7.10	8.20	7.65						5.95	5.95
	7.30	7.40	6.95	8.30	7.55				6.20		5.90	5.95
	7.35	7.40	6.75	8.45	7.45				8.45		5.90	6.45
	7.35	7.45	6.60	8.30	7.35			7.25	7.85	4.80	5.85	6.55
	7.40	7.40	6.60	8.10	7.15			9.05	6.70	4.80	5.80	6.50
	7.30	7.40	6.65	7.90	7.00			11.10	6.25	4.80	5.70	6.40
	7.40	7.40	7.20	7.90	6.95			8.45	6.15	4.80	5.70	6.45
	7.35	7.40	7.30	7.70	6.65			7.85	6.00	4.80	5.80	6.50
	7.30		7.25	7.85	8.20			7.45	5.85	4.90	6.00	6.70
	7.35		7.25	7.85	8.35			7.40	5.55	4.90	6.00	6.45
	7.35		7.20		7.65			6.65		4.90		6.40

[a] *There was no flow on days for which no gage heights are given.*

Estimated monthly discharge of the Rio Grande near San Marcial, N. Mex.

[Drainage area, 28,067 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	500	300	370	22,731	0.0132	0.0152
February	480	220	314	17,435	.0112	.0117
March	250	50	129	7,954	.0046	.0053
April	1,650	0	674	40,106	.0240	.0268
May	1,710	35	436	26,787	.0155	.0179
June	560	0	108	6,407	.0038	.0042
July	[a] 0	[a] 0	[a] 0	[a] 0	[a] 0	[a] 0
August	10,500	0	800	49,210	.0285	.0329
September	2,460	0	224	13,349	.0080	.0089
October	75	0	13	823	.0005	.0006
November	180	15	78	4,641	.0028	.0031
December	350	65	184	11,286	.0066	.0076
The year	10,500	0	278	200,729	.0099	.1342

[a] River dry June 14 to August 11, inclusive.

RIO GRANDE AT WATER TANK, NEAR RIO GRANDE, OR BUCKMAN, N. MEX.

Three miles below Embudo the river emerges into Espanola Valley, through which it continues for a few miles and then enters White Rock Canyon, flowing through that canyon for 30 miles. At the lower end of this canyon the river emerges into Albuquerque Valley, and so continues down to about Socorro. This valley averages from 1 to 3 miles in width, and has been irrigated for a great many years by the Mexican settlers. Their primitive methods of irrigation are very wasteful of the waters, so that the duty of water in this section, about 17 acres per second-foot, is not as high as it might be. During the last few years, however, a number of important and modern irrigation systems have been planned and built in the vicinity of Albuquerque. The gaging station, established February 3, 1895, is located about one-fourth of a mile above Water Tank, a section on the Santa Fe Southern Railroad, below Espanola. It was established by Arthur P. Davis and P. E. Harroun on February 1, 1895. The observer is Thomas Dupre, section foreman, whose house is distant from the gaging station about one-fourth of a mile. The inclined portion of the gage is marked from 3.5 feet to 10.6 feet; the vertical portion from 10.6 feet to 16 feet. The inclined part of the gage is braced with wood and anchored with stones. The upper part is set in

ground, leaning against a huge boulder, and is held in that posi- by wire, wel tightened. The highest point of the boulder is ked with a black cross, and is 6.815 feet above the 11-foot mark. surement was made from gaging box suspended from cable placed es just above the gage. The channel is sandy and shifting.

Discharge measurements of the Rio Grande near Rio Grande, N. Mex.

[Made by P. E. Harroun and O. B. Powell.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
ary 23	5.0	484	July 14	3.8	93
ary 12	5.05	485	July 17	3.8	110
h 31	5.3	518	July 21	5.0	419
3	5.3	519	July 24	5.0	416
7	6.7	1,243	July 28	4.3	208
10	7.5	1,744	July 31	4.0	112
14	7.9	2,252	August 4	4.2	148
17	7.5	1,952	August 7	4.7	233
22	7.6	2,190	August 11	6.15	[a] 2,009
25	6.5	1,333	August 14	4.6	241
28	6.6	1,403	August 18	4.3	172
	6.5	1,164	August 21	3.9	106
	6.6	1,271	August 25	8.1	2,853
	6.3	1,109	August 28	6.0	848
2	6.7	1,267	September 1	4.5	232
5	6.7	1,391	September 4	4.1	150
9	6.1	895	September 8	4.1	139
3	5.6	633	September 11	3.8	85
6	5.2	516	September 15	4.0	117
8	7.4	1,877	September 18	3.8	122
0	6.6	1,561	September 21	10.7	6,592
	6.6	1,449	September 25	4.7	309
	5.8	857	September 29	4.7	250
	5.5	672	October 2	4.6	255
2	5.0	421	October 6	4.7	325
6	4.7	332	October 9	4.7	276
9	4.3	180	October 13	4.7	265
3	4.0	123	October 16	4.7	294
7	3.8	85	October 20	4.7	276
0	3.6	71	October 23	4.7	268
	3.5	62	October 27	4.6	266
	3.6	78	October 30	4.7	285
0	3.8	125	November 3	4.7	282

[a] Abnormally large.

Discharge measurements of the Rio Grande near Rio Grande, N. Mex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
November 6	4.7	264	December 4	4.4	[illegible]
November 10	4.7	261	December 8	4.8	[illegible]
November 13	5.0	403	December 11	4.8	[illegible]
November 17	4.7	278	December 15	4.8	[illegible]
November 21	4.7	295	December 18	4.4	[illegible]
November 24	4.9	399	December 22	4.6	[illegible]
November 27	4.6	273	December 26	4.7	[illegible]
December 1	4.5	276	December 29	4.7	[illegible]

Daily gage height, in feet, of the Rio Grande near Rio Grande, N. Mex.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	5.00	4.95	5.15	5.25	6.40	6.70	3.55	5.10	4.45	4.65	4.70	4.50
2	5.05	4.95	5.10	5.35	6.40	6.70	3.60	4.25	4.40	4.60	4.70	4.65
3	5.00	4.95	5.10	5.50	6.40	6.45	3.55	4.10	4.30	4.70	4.70	4.50
4	5.10	4.90	5.10	5.50	6.50	6.15	3.50	4.05	4.10	4.70	4.60	4.40
5	5.10	4.95	5.10	5.55	6.50	6.00	3.50	5.60	4.10	4.80	4.65	4.70
6	5.10	4.95	5.00	6.05	6.35	5.75	3.55	6.35	3.95	4.70	4.65	4.70
7	5.05	4.95	5.00	6.20	6.35	5.70	3.55	4.70	4.15	4.70	4.70	4.75
8	5.05	5.05	5.05	6.95	6.40	5.60	3.55	4.80	4.15	4.65	4.70	4.75
9	5.05	5.05	5.05	7.55	6.55	5.45	3.90	4.50	3.95	4.70	4.70	4.75
10	5.10	5.05	5.25	7.80	6.55	5.15	4.75	4.25	3.90	4.70	4.70	4.75
11	5.10	5.05	5.55	8.05	6.75	5.05	3.65	5.90	3.80	4.70	4.60	4.75
12	5.00	5.05	5.55	8.45	7.20	4.95	3.70	5.30	3.90	4.70	5.05	4.75
13	5.00	5.05	5.40	8.10	7.35	5.15	3.80	4.70	3.90	4.65	5.00	4.90
14	5.05	5.00	5.40	7.95	6.90	4.95	3.65	4.75	3.90	4.65	5.00	4.90
15	5.05	5.00	5.25	7.55	6.65	4.75	3.60	4.50	3.95	4.70	4.90	4.90
16	5.05	5.00	5.20	7.15	6.45	4.65	3.50	4.25	3.85	4.70	4.85	4.65
17	5.00	5.05	5.20	7.55	6.25	4.50	4.25	4.50	3.85	4.70	4.70	4.10
18	5.15	5.15	5.10	7.65	6.20	4.35	4.50	4.30	3.90	4.70	4.70	4.45
19	5.10	5.10	5.45	7.65	6.20	4.30	6.15	4.15	4.05	4.60	4.70	5.05
20	5.10	5.15	5.60	7.90	6.05	4.15	7.80	4.00	6.20	4.70	4.70	4.65
21	5.10	5.05	5.60	7.80	5.95	4.10	5.20	3.96	10.60	4.70	4.70	4.65
22	5.00	5.15	5.75	7.50	5.85	4.00	5.45	4.90	7.35	4.70	4.80	4.65
23	4.95	5.20	5.65	6.75	5.50	3.95	4.35	5.55	5.80	4.70	4.90	4.65
24	5.00	5.20	5.55	6.60	5.30	3.90	4.55	6.35	4.90	4.70	4.90	4.65
25	4.95	5.20	5.40	6.60	5.25	3.95	4.45	7.60	4.80	4.60	4.90	4.75
26	5.00	5.35	5.35	6.60	5.20	3.85	4.45	7.25	4.75	4.60	4.70	4.80
27	4.75	5.35	5.40	6.55	7.80	3.75	4.35	6.15	4.60	4.60	4.70	4.80
28	4.80	5.25	5.25	6.50	7.25	3.60	4.30	5.60	4.60	4.60	4.65	4.90
29	4.95	.....	5.35	6.45	7.05	3.60	4.25	5.15	4.70	4.65	4.60	4.70
30	5.00	.....	5.30	6.45	6.65	3.60	4.15	4.95	4.65	4.70	4.60	4.60
31	4.95	.....	5.30	.....	6.65	.....	4.05	4.70	.....	4.70	.....	4.60

Estimated monthly discharge of the Rio Grande near Rio Grande, N. Mex.

[Drainage area, 14,050 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	495	455	482	29,643	0.034	0.039
February	540	475	489	27,183	.035	.036
March	735	480	548	33,709	.039	.045
April	3,200	510	1,640	97,577	.117	.131
May	2,230	520	1,196	73,567	.085	.098
June	1,530	70	474	28,215	.034	.038
July	2,200	60	272	16,730	.019	.022
August	2,300	105	556	34,165	.040	.046
September	6,460	85	484	28,790	.034	.038
October	345	255	279	17,157	.020	.023
November	420	250	309	18,386	.022	.025
December	440	200	313	19,220	.022	.025
The year	6,460	60	587	424,342	.042	.566

RIO GRANDE AT EMBUDO, N. MEX.

Embudo is a railroad station on the Denver and Rio Grande Railroad, in Rio Arriba County. The station is in a narrow canyon above the head of the valley in which Espanola and other towns are located, and in which the river Chama joins the Rio Grande. In November, 1888, an examination was made along the main stream for the purpose of selecting a point at which the total discharge of the Rio Grande entering New Mexico could be ascertained. Coming from Colorado southward, this is the first point at which the railroad reaches the river, and for this reason it was finally determined to establish a river station here. Measurements were begun at the rocky narrows, about a mile above the railroad station, but in the spring of 1889 the observations were transferred to a point directly behind the railroad station, for convenience of the observer and consequent reduction of expense. The inclined gage, constructed at that time, is made of scantling, 4 by 4 inches, spiked to posts set firmly in the ground. It is on the right hand side of the river, at a place where the slopes are very gentle, and therefore is of considerable length in order to reach out to the low-water channel. It is graduated from about 7.30 feet, the low-water mark, up to 16 feet. The point 3.50 would correspond approximately to the deepest part of the section. The gage is about 75 feet above the cable and is in three parts with different slopes. The cable is five-

eighths-inch wire, with 19 steel strands. It is fastened to a cedar tree on the left-hand side and to sand anchors on the right. Measurements were originally made from a boat held by traveling pulleys running on the cable. The boat being washed away by flood, later measurements were made from a box suspended from the cable.

Bench mark No. 1 is on a rock near the end of the cable, on the left-hand bank, marked "B. M." with white paint. It is 20.66 feet above zero of the gage. Bench mark No. 2 is on a rock about 100 feet above the cable, on the left bank of the river, and is marked "B. M." with white paint. It is 18.79 feet above datum. Bench mark No. 3 is a notch cut in the southeast corner of the station house, about 2 feet above the level of the platform, and is 30.48 feet above datum.

Discharge measurements of the Rio Grande at Embudo, N. Mex.

[Made by P. E. Harroun and O. B. Powell.]

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
January 21	7.5	386	July 1	6.8	147
February 10	7.6	422	July 4	6.8	140
March 28	7.8	410	July 8	6.8	137
April 9	8.2	631	July 12	6.8	140
April 12	8.5	773	July 15	6.8	144
April 15	8.4	771	July 19	6.9	150
April 18	8.3	667	July 22	7.1	192
April 23	8.4	741	July 25	6.8	154
April 26	8.1	604	July 29	6.9	164
April 29	8.1	632	August 1	6.8	158
May 3	8.3	715	August 5	6.8	156
May 6	8.5	849	August 8	7.2	236
May 9	8.6	900	August 13	7.0	191
May 13	8.8	1,099	August 16	6.9	161
May 16	8.5	901	August 19	6.8	152
May 20	8.3	814	August 23	7.0	176
May 24	7.8	471	August 26	8.2	785
May 27	8.1	611	August 29	7.1	227
May 31	8.7	990	September 2	7.0	198
June 4	8.6	917	September 6	6.9	166
June 7	8.3	697	September 9	6.9	164
June 10	7.8	450	September 12	6.9	167
June 13	7.5	364	September 16	6.9	165
June 17	7.2	240	September 19	6.9	169
June 21	7.0	196	September 23	7.2	250
June 25	6.9	179	September 26	7.1	223
June 28	6.9	152	September 30	7.1	239

Discharge measurements of the Rio Grande at Embudo, N. Mex.—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1902.	*Feet.*	*Second-feet.*	1902.	*Feet.*	*Second-feet.*
r 2	7.1	217	November 18	7.1	225
r 6	7.2	217	November 21	7.3	235
r 10	7.2	227	November 25	7.3	247
r 14	7.2	238	November 28	7.1	218
r 17	7.2	229	December 2	7.2	252
r 21	7.2	228	December 5	7.1	225
r 24	7.2	240	December 9	7.2	246
r 28	7.2	230	December 12	7.3	246
r 31	7.2	217	December 16	7.3	244
ıber 4	7.2	218	December 20	7.5	316
ıber 7	7.2	219	December 23	7.3	268
ıber 11	7.2	226	December 27	7.3	266
ıber 14	7.2	228	December 31	7.2	249

Daily gage height, in feet, of the Rio Grande at Embudo, N. Mex.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	7.60	7.40	8.00	7.70	8.10	9.10	6.80	6.80	7.00	7.10	7.20	7.20
.....	7.70	7.70	7.90	7.75	8.20	9.00	6.80	6.80	7.05	7.10	7.20	7.20
.....	7.65	7.50	8.00	7.80	8.30	8.85	6.80	6.80	7.00	7.25	7.20	7.20
.....	7.70	7.50	8.00	7.80	8.40	8.65	6.80	7.20	7.00	7.20	7.20	7.15
.....	7.65	7.55	7.85	7.80	8.40	8.55	6.80	7.40	7.00	7.20	7.20	7.15
.....	7.65	7.55	7.85	7.85	8.45	8.45	6.80	7.60	6.95	7.20	7.20	7.20
.....	7.65	7.60	7.85	7.90	8.50	8.25	6.80	7.00	6.90	7.20	7.20	7.25
.....	7.70	7.55	7.85	8.05	8.50	8.10	6.80	7.20	6.90	7.20	7.20	7.25
.....	7.70	7.60	8.05	8.25	8.55	7.90	6.80	7.05	6.90	7.20	7.20	7.20
.....	7.70	7.60	8.10	8.30	8.60	7.80	6.80	6.90	6.90	7.20	7.20	7.20
.....	7.65	7.60	8.15	8.55	8.75	7.70	6.80	7.65	6.90	7.20	7.25	7.20
.....	7.60	7.65	8.00	8.55	8.80	7.60	6.80	7.15	6.90	7.20	7.50	7.30
.....	7.65	7.70	7.90	8.55	8.80	7.55	6.80	7.05	6.90	7.20	7.25	7.30
.....	7.55	7.60	7.95	8.50	8.80	7.35	6.80	7.00	6.90	7.20	7.25	7.30
.....	7.65	7.65	7.90	8.40	8.70	7.25	6.80	7.00	6.90	7.20	7.20	7.20
.....	7.65	7.65	7.80	8.40	8.55	7.20	6.80	6.90	6.90	7.20	7.20	7.20
.....	7.65	7.75	7.80	8.40	8.40	7.15	6.90	7.05	6.90	7.20	7.20	7.20
.....	7.60	7.75	7.70	8.30	8.40	7.10	6.90	6.95	6.90	7.20	7.10	7.20
.....	7.60	7.80	8.00	8.40	8.35	7.05	6.90	6.85	6.95	7.20	7.15	7.50
.....	7.70	7.70	8.20	8.40	8.25	7.00	7.35	6.80	7.05	7.20	7.20	7.50
.....	7.60	7.90	8.10	8.50	8.15	7.00	7.30	6.85	8.75	7.20	7.25	7.40
.....	7.55	7.85	8.10	8.45	8.05	7.00	7.00	7.00	7.40	7.20	7.30	7.45
.....	7.50	7.85	8.00	8.45	7.95	7.00	6.90	7.15	7.25	7.30	7.30	7.35
.....	7.60	7.85	7.95	8.35	7.80	6.90	6.85	7.15	7.15	7.20	7.35	7.45
.....	7.60	7.90	7.95	8.25	7.70	6.90	6.90	7.50	7.10	7.20	7.25	7.45
.....	7.60	8.00	7.85	8.10	7.75	6.90	6.90	8.25	10	7.25	7.10	7.35
.....	7.50	8.05	7.80	8.10	8.00	6.90	6.90	7.45	10	7.30	7.10	7.35
.....	7.60	8.00	7.80	8.10	8.20	6.90	6.90	7.20	10	7.25	7.10	7.40
.....	7.60	.....	7.95	8.10	8.35	6.80	6.90	7.10	10	7.20	7.15	7.35
.....	7.60	.....	7.85	8.10	8.55	6.80	6.90	7.10	10	7.20	7.20	7.30
.....	7.50	.....	7.70	.....	8.80	.....	6.80	7.00		7.20	.....	7.30

Estimated monthly discharge of the Rio Grande at Embudo, N. Mex.

[Drainage area, 10,090 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	460	390	430	26,420	0.043	0.050
February	585	360	462	25,676	.046	.048
March	630	410	532	32,698	.053	.061
April	800	450	661	39,352	.066	.074
May	1,100	420	798	49,061	.079	.091
June	1,360	130	440	26,202	.044	.049
July	280	140	158	9,719	.016	.018
August	820	150	246	15,154	.024	.028
September	1,050	165	228	13,587	.023	.026
October	260	215	231	14,182	.023	.027
November	310	220	231	13,736	.023	.026
December	315	240	264	16,245	.026	.030
The year	1,360	130	390	282,032	.039	.528

RIO GRANDE NEAR CENICERO, COLO.

This station was located on June 28, 1899, by A. L. Fellows. It is at the State bridge across the Rio Grande, at a point near the Colorado-New Mexico State line and about 4 miles west of Eastdale, Colo. The station is favorably located for the purpose, the cross section being fairly uniform, the channel regular and not liable to overflow.

There are two gage rods, one for high water and the other for low water. The high-water rod is a 2 by 6 inch timber attached to the west side of the central downstream cylinder of the bridge. The low-water rod is a scale, marked in feet and tenths, on the perpendicular face of a large bowlder about a hundred yards below the bridge. The channel is in most respects an excellent one. The bed consists of bowlders and rock, and is subject to little change; the banks are high and are not subject to overflow. Gagings can be made at the bridge, but during low water they are usually made by wading. On June 22, 1900, both gages were referred to a bench mark consisting of a chiseled point marked "B. M." on the face of the lava bluff under the west end of the bridge, 7.42 feet above gage datum. The station is an extremely important one, giving, as it does, the discharge of the river at the Colorado State line, including practically all of the Colorado drainage.

Roman Mondragon, who keeps a store at the west end of the bridge, has kept the records during the last year.

The following measurement was made in 1902 by A. L. Fellows:

July 9: Gage height, 0.60 feet; discharge, 6 second-feet.

Daily gage height, in feet, of the Rio Grande near Cenicero, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.80	2.10	2.40	1.50	1.40	1.80	0.80	0.80	0.70	0.90	0.90	0.90
2	1.80	2.10	2.50	1.60	1.60	1.70	.80	.80	.70	.90	.90	.90
3	1.80	2.00	2.60	1.60	1.70	1.60	.80	.80	.70	.90	.90	.90
4	1.80	2.00	2.60	1.60	1.80	1.50	.80	.80	.70	.90	.90	.90
5	1.80	2.00	3.00	1.60	1.90	1.50	.80	.80	.70	.90	.90	.90
6	1.80	2.00	3.00	1.60	1.90	1.40	.80	.80	.70	.90	.90	.90
7	1.80	2.00	2.60	1.60	1.90	1.40	.80	.80	.70	.90	.90	.90
8	1.80	2.00	2.50	1.70	1.90	1.40	.80	.80	.80	.90	.90	.90
9	1.80	2.00	2.40	1.70	1.90	1.40	.80	.80	.80	1.00	.80	.90
10	1.80	2.00	1.70	1.80	1.90	1.30	.80	.80	.80	1.00	.80	1.00
11	1.80	2.00	1.70	1.90	1.90	1.30	.80	.80	.80	1.00	.80	1.00
12	1.80	2.00	1.70	1.90	1.90	1.30	.80	.80	.90	1.00	.90	1.00
13	1.80	2.00	1.70	1.90	1.90	1.30	.80	.80	.90	1.00	.90	1.00
14	1.80	2.10	1.70	1.90	1.90	1.30	.80	.80	.90	1.00	.90	1.00
15	1.90	2.20	1.70	1.80	2.00	1.20	.80	.80	90	.90	.90	1.00
16	1.90	2.20	1.70	1.80	2.00	1.20	.80	80	90	.90	.90	1.00
17	1.90	2.20	1.90	1.80	1.90	1.20	.80	70	90	.90	.90	1.00
18	1.90	2.30	1.70	1.70	1.90	1.20	.80	70	90	.90	.90	1.00
19	1.90	2.30	1.70	1.70	1.90	1.20	.80	70	90	.90	.90	1.00
20	1.90	2.40	1.60	1.70	1.90	1.20	.80	70	90	.90	.90	1.00
21	1.90	2.40	1.60	1.70	1.90	1.20	.80	60	90	.80	.90	1.00
22	2.10	2.40	1.60	1.70	1.90	1.10	.80	60	90	.80	.90	1.00
23	2.10	2.40	1.60	1.70	1.90	1.10	.80	60	.90	.80	.90	1.00
24	2.10	2.40	1.60	1.90	1.90	1.10	.80	60	.90	.80	.90	1.00
25	2.10	2.40	1.60	1.50	1.90	1.00	.80	60	.90	.90	.90	1.00
26	2.10	2.40	1.90	1.50	2.00	1.00	.80	60	.90	.90	.90	1.00
27	2.10	2.40	1.70	1.50	2.00	.90	.80	70	.90	.90	.90	1.00
28	2.10	2.40	1.60	1.50	2.00	.90	.80	70	.90	.90	.90	.80
29	2.10	.....	1.60	1.50	2.00	.80	.80	70	.90	.90	.90	.70
30	2.10	.....	1.60	1.50	1.90	.80	.80	70	.90	.90	.90	.70
31	2.10	.....	1.50		1.80	.....	.80	70	.....	.90	.....	.80

Rating table for the Rio Grande near Cenicero, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.6	6	1.8	414	3.0	1,494	4.2	2,574
0.8	22	2.0	594	3.2	1,674	4.4	2,754
1.0	44	2.2	774	3.4	1,854	4.6	2,934
1.2	82	2.4	954	3.6	2,034	4.8	3,114
1.4	142	2.6	1,134	3.8	2,214	5.0	3,294
1.6	244	2.8	1,314	4.0	2,394		

Estimated monthly discharge of the Rio Grande near Cenicero, Colo.

[Drainage area, 7,695 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep inc
1902.						
January	684	414	521	32,035	0.0677	(
February	954	594	758	42,097	.0985	
March	1,494	185	549	33,757	.0713	
April	504	185	315	18,744	.0409	
May	594	142	490	30,129	.0637	
June	414	22	114	6,783	.0148	
July	22	22	22	1,353	.0029	
August	22	6	17	1,045	.0022	
September	31	14	26	1,547	.0034	
October	44	22	32	1,968	.0042	
November	31	22	30	1,785	.0039	
December	44	14	37	2,275	.0048	
The year	1,494	6	243	173,518	.0315	

RIO GRANDE NEAR DEL NORTE, COLO.

Measurements and observations were first begun in the vicinit Del Norte in 1889 by George T. Quinby. The object of the n urements was to obtain the flow of the river before water was dive for the agricultural region of the San Luis Valley, and, by a comp son of this with the figures obtained at Embudo, to acquire data the effect of the numerous ditches taking out water between the points. The river 25 miles above Del Norte flows out of the ca at Wagon Wheel Gap. Little water, however, is diverted until edge of the San Luis Valley is reached, the largest canal heading the town of Del Norte. During freshets the river divides into a r ber of channels, making it difficult to obtain measurements near t In order to avoid the expense of establishing a station during tin high water, the first measurements—those about June 1—were r from several bridges crossing the numerous branches. The re were not wholly satisfactory, and on June 25 a station was establi above the branches. Later a locality about 2 miles farther up chosen.

The station is about 2 miles west of the town of Del Norte, a the main canal taking water from the Rio Grande and is above al irrigating ditches of importance. The river flows in one cha about 175 feet wide and of very regular section. The banks on side are steep, and the water is reported never to overflow.

course of the stream is straight for several hundred yards both above and below the section. An inclined gage is set, at an angle of about 30° to the horizontal, on the left bank, and is referred to bench marks. As noted on October 10, 1891, No. 1 is a large nail in the root of a tree 15 feet northwest of the end of the cable on left bank of river. Bench mark No. 2 is a large nail in the root of a tree 25 feet southwest of the end of the inclined gage. Both bench marks are 7.54 feet above the datum of the gage.

On June 16, 1900, the gage rod was connected with an iron bench mark of the United States Geological Survey, set in the ground about 25 feet south of the rod, the zero of the rod being 9.25 feet below the bench mark

Gagings were first made from a flatboat, 4 feet wide and 14 feet long, attached by rope and tackle to a five-eights-inch wire cable fastened to a large cottonwood tree on the left bank, and to a sand anchor on the right bank. They are now made by means of a car which travels across the river along a steel cable, the distance being marked on a tag wire. The channel is excellent, the water, although falling rapidly, seldom scouring, and the bed, therefore, remaining practically the same from year to year. The bed of the channel is covered with small bowlders and the sides, although not high, have never been known to overflow. The observer is J. S. Regan, who has kept the records regularly ever since the station was established.

The following discharge measurements were made during 1902 by A. L. Fellows and J. E. Field:

April 24: Gage height, 1.90 feet; discharge, 493 second-feet.
July 8: Gage height, 1.31 feet; discharge, 210 second-feet.

Daily gage height, in feet, of the Rio Grande near Del Norte, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.68	1.60	1.68	1.40	2.84	2.66	1.26	1.10	1.34	1.44	1.34	1.84
2	1.62	1.66	1.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	1.62	1.66	1.60	1.48	3.24	2.44	1.24	1.06	1.30	1.46	1.36	2.00
4	1.62	1.66	1.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	1.58	1.66	1.60	1.60	2.86	2.34	1.24	1.06	1.24	1.40	1.32	1.92
6	1.58	1.66	1.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	1.58	1.66	1.60	1.74	2.94	2.30	1.22	1.08	1.20	1.40	1.32	1.96
8	1.58	1.66	1.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	1.58	1.62	1.34	2.00	2.86	2.24	1.26	1.08	1.14	1.48	1.32	1.84
10	1.58	1.62	1.34	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	1.58	1.62	1.34	1.94	2.74	2.10	1.22	1.08	1.12	1.44	1.30	1.80
12	1.52	1.62	1.34	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	1.52	1.62	1.34	1.86	2.72	2.14	1.20	1.14	1.10	1.40	1.38	1.82
14	1.52	1.62	1.34	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	1.52	1.62	1.34	1.84	2.70	1.90	1.16	1.12	1.10	1.38	1.32	1.84
16	1.52	1.70	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	1.52	1.70	1.40	1.82	2.64	1.78	1.10	1.08	1.10	1.34	1.28	1.80
18	1.52	1.70	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	1.56	1.70	1.40	2.04	2.40	1.66	1.20	1.04	1.12	1.30	1.28	1.82

Daily gage height, in feet, of the Rio Grande near Del Norte, Colo.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
20	1.56	1.70	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....
21	1.56	1.70	1.40	2.46	2.16	1.50	1.20	1.00	1.40	1.30	1.30	1.80
22	1.56	1.70	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	1.56	1.68	1.26	2.34	2.04	1.50	1.16	1.06	1.52	1.32	1.30	1.78
24	1.56	1.68	1.26	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	1.56	1.68	1.26	1.86	2.00	1.42	1.12	1.96	1.52	1.32	1.28	1.82
26	1.60	1.68	1.26	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	1.60	1.68	1.26	2.42	2.06	1.34	1.14	1.70	1.54	1.26	1.34	1.86
28	1.60	1.68	1.26	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	1.60	.....	1.26	2.46	2.64	1.30	1.14	1.48	1.50	1.22	2.00	1.82
30	1.60	.....	1.36	.....	.....	.....	.....	.....	.....	.....	.....	.....
31	1.60	.....	1.36	.....	2.84	.....	1.10	1.40	.....	1.30	.....	1.80

Rating table for the Rio Grande near Del Norte, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	69	2.2	812	3.4	1,972	4.6	3,651
1.2	159	2.4	976	3.6	2,218	4.8	3,951
1.4	265	2.6	1,148	3.8	2,480	5.0	4,251
1.6	385	2.8	1,330	4.0	2,758	5.2	4,551
1.8	518	3.0	1,528	4.2	3,051	5.4	4,851
2.0	660	3.2	1,742	4.4	3,351	5.6	5,151

Estimated monthly discharge of the Rio Grande near Del Norte, Colo.

[Drainage area, 1,120 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
January	437	336	381	23,427	0.28	0.32
February	450	385	412	22,811	.29	.29
March	437	189	438	26,932	.31	.36
April	1,027	265	638	37,964	.45	.50
May	1,787	660	1,169	71,879	.84	.97
June	1,201	210	618	36,774	.44	.49
July	189	112	152	9,346	.12	.14
August	631	69	180	11,068	.13	.15
September	348	112	206	12,258	.15	.17
October	312	169	242	14,880	.17	.2
November	660	200	249	14,817	.18	.2
December	660	518	547	33,634	.39	.4
The year	1,787	69	436	315,790	.31	4.2

INDEX.

Page.

Anadarko, Okla., stream measurements at 139-140
Angelina River, Texas, measurements of.. 142
Arkansas City, Kans., stream measurements at 119-120
Arkansas River, measurements of, at Arkansas City, Kans 119-120
measurements of, at Barton, Colo.... 125-126
at Dodge, Kans 122
at Hutchinson, Kans 120-122
at Pueblo, Colo 130-133
at Salida, Colo 136-138
at Syracuse, Kans 123-125
near Canyon, Colo 133-136
near Nepesta, Colo 128-130
near Rockyford, Colo 126-127
stream measurements in basin of 113-138
Arkins, Colo., stream measurements near.. 79-81
Arlington, Nebr., stream measurements near 51-53
Austin, Tex., stream measurements at... 149-153
Bailey, Colo., stream measurements at 94
Ballinger, Tex., stream measurements at.. 152
Barnetts Ford, Tex., stream measurements at 156
Barton, Colo., stream measurements at.. 125-126
Barton Springs, Texas, measurements of. 152-153
Bear Creek, Colorado, measurements of.... 89, 94
Bear Creek, Texas, measurements of..... 154
Benkleman, Nebr., stream measurements at 113
Big Bend, stream measurements at 94
Big Cypress, Texas, measurements of 140
Big Sandy, Tex., stream measurements near 141
Big Sandy River, Texas, measurements of. 141
Big Sioux River, Nebraska, measurements of 49
Big Sioux River, South Dakota, measurements of 15-16
Big Thompson Creek, Colorado, measurements of 79-81
Bighorn River, Wyoming, measurements of 23-24
Bigspring, Nebr., stream measurements at. 72-73
Blue Creek, Nebraska, measurements of... 93
Blue River, Kansas, measurements of..... 97-99
Blue River, Nebraska, measurements of ... 112
Bozeman, Mont., stream measurements near 43-45
Brazos River, measurements of, at Richmond, Tex 147
measurements of, at Waco, Tex..... 143-146
stream measurements in basin of 143-148
Bridgeport, Nebr., stream measurements at. 64-66

Page.

Brush Creek, Wyoming, measurements of.. 94
stream measurements at 94
Buffalo, Wyo., stream measurements at.... 20
Buffalo Creek, Nebraska, measurements of. 92
Buffalo Springs, Colo., stream measurements near 94
Burwell, Nebr., stream measurements at... 92
Calamus Creek, Nebraska, measurements of. 92
Camden, Ark., stream measurements at.... 140
Canadian River, Oklahoma, measurements of 114
Canyon, Colo., stream measurements near. 133-136
Cascade, Mont., stream measurements at .. 35-36
Cenicero, Colo., stream measurements near 192-194
Center Creek, Nebraska, measurements of . 112
Chalk Creek, Colorado, measurements of... 138
Clear Creek, Colorado, measurements of... 84-86
Clear Creek, Texas, measurements of 156
Clear Creek, Wyoming, measurements of .. 20, 94
Cody, Wyo., stream measurements at 21-23
Colorado River, measurements of, at Austin, Tex 149-152
measurements of, at Columbus, Tex.... 149
miscellaneous 152
stream measurements in basin of..... 148-156
Columbus, Nebr., stream measurements at. 55-57
stream measurements near..... 57-59
Columbus, Tex., stream measurements at.. 149
Comal Creek, Texas, measurements of 157
Comal Spring Creek, Tex., stream measurements at 157
Comfort, Tex., stream measurements at.... 157
Como, Colo., stream measurements at..... 94
Conifer, Colo., stream measurements near.. 94
Corlett, Wyo., stream measurements at 94
Cow Creek, Wyoming, measurements of... 94
Craig, Mont., stream measurements at..... 37
Crete, Nebr., stream measurements at..... 112
Crooked Creek, Nebraska, measurements of. 112
Crow Creek, Montana, measurements of... 50
Cuero, Tex., stream measurements near... 156
Culbertson, Nebr., stream measurements at 112-113
Deer Park Creek, Colorado, measurements of 94
Del Norte, Colo., stream measurements near 194-196
Denver, Colo., stream measurements at.... 86-88
Devils Gate, Wyo., stream measurements at. 72
Devils River, Texas, measurements of.... 164-165
Devilsriver, Tex., stream measurements at 164-165

Page.

Devilsriver, Tex., stream measurements near 161-163
Dodge, Kans., stream measurements at.... 122
Eagle Pass, Tex., stream measurements at 158-160
El Paso, Tex., stream measurements near. 181-183
Elk Creek, Colorado, measurements of..... 94
Elkhorn River, measurements of, near Arlington, Nebr..... 51-53
measurements of, near Norfolk, Nebr. 53-55, 92
Ellsworth, Kans., stream measurements at 110-112
Elreno, Okla., stream measurements near.. 114
Embudo, N. Mex., stream measurements at 189-192
Enders, Nebr., stream measurements at.... 112
Erskine Falls., Tex., stream measurements near 157
Fairplay, Colo., stream measurements at... 94
Forkscreek, Colo., stream measurements at. 84-86
FourmileCreek, Colorado, measurements of. 94
Fort Hancock, Tex., stream measurements near 179-180
Fort McKavett, Tex., stream measurements near 156
Fort Niobrara, Nebr., stream measurements at 49
Fort Steele, Wyo., stream measurements at. 94
Franklin, Nebr., stream measurements at.. 113
Frenchman River, Nebraska, measurements of 112
Gallahers Ferry, Mont., stream measurements at 37
Gallatin Ferry, Mont., stream measurements at 37
Gallatin River, Montana, measurements of. 38-40
Garland, Ark., stream measurements at ... 140
Grand Encampment Creek, Wyoming, measurements of 94
Granite Canyon, Wyo., stream measurements at 94
Greatfalls, Mont., stream measurements at. 37
Guadalupe River, Texas, measurements of, miscellaneous 157
measurements of, near Cuero, Tex..... 156
stream measurements in basin of 156-157
Guernsey, Wyo., stream measurements at.. 68-70
Haigler, Nebr., stream measurements at... 112
Halls Gulch, Colorado, measurements of... 94
Hatton, Wyo., stream measurements near.. 70-71
Havre, Mont., stream measurements at 28-31
Hecla, Wyo., stream measurements near... 75-77
Hot Wells, Tex., stream measurements at.. 157
Hutchinson, Kans., stream measurements at 120-122
Iola, Kans., stream measurements at 115-116
Ives, Nebr., stream measurements at..... 112-113
Jefferson, Colo., stream measurements at.. 94
Jefferson Creek, Colorado, measurements of 94
Jefferson River, Montana, measurements of. 47-49
Johnsons Fork (Gaudalupe), Texas, measurements of 157
Johnson Fork (Llano) Texas, measurements of 154
Jonah, Tex., stream measurements at..... 148
Julesburg, Colo., stream measurements at. 73-75

Pag

Junction, Kans., stream measurements at. 100-1
Junction City, Tex., stream measurements near 1
Kansas River, Kansas, measurements of.... 95-
stream measurements in basin of..... 95-1
Kearney, Nebr., stream measurements at..
Kearney, Wyo., stream measurements at ..
Kersey, Colo., stream measurements at 77-
Kimball, Nebr., stream measurements at ..
Lampasas, Tex., stream measurements at . 1
Lampasas, Texas, Sulphur Fork of, measurements of 1
Landa Mill Race, Tex., stream measurements at 1
Langtry, Tex., stream measurements at . 172-1
Las Moras Creek, Texas, measurements of . 1
Lawrence Fork, Nebraska, measurements of .....
Lecompton, Kans., stream measurements at 95-
Lexington, Nebr., stream measurements near 59-
Liberty, Kans., stream measurements near 116-
Lincoln, Nebr., stream measurements at...
Little Laramie River, Wyoming, measurements of 70-
Little River, Texas, measurements of 147-
Livingston, Mont., stream measurements near 24-
Llano, Tex., stream measurements near ... 1
Llano River, Texas, measurements of.... 153-
Lodgepole Creek, Nebraska, measurements of .....
Logan, Mont., stream measurements at 38-
Lonergan Creek, Nebraska, measurements of .....
Longpine, Nebr., stream measurements at..
Longpine Creek, Nebraska, measurements of .....
Lost Creek, Nebraska, measurements of....
Loup River, Nebraska, measurements of... 55
Lufkin, Tex., stream measurements near...
Lyons, Colo., stream measurements at 81
Madison River, Montana, measurements of. 46
Malta, Mont., stream measurements at 26
Manhattan, Kans., stream measurements near 97
Marais des Cygnes River, Kansas, measurements of 14
Marias River, Montana, measurements of.. 32
Marble Falls, Tex., stream measurements at.
Marguerette Flume, Texas, measurements of 168-
McCook, Nebr., stream measurements at...
Medicine Bow River, Wyoming, measurements of .....
Menardville, Tex., stream measurements at .....
Michigan Creek, Colorado, measurements of .....
Middle Creek, Montana, measurements of.. 4
Middle Crow Creek, Wyoming, measurements of..... 75-77
Middle Loup River, Nebraska measurements of .....

Page.
Midvale, Mont., stream measurements at.. 34-35
Milk River, measurements of, at Havre, Mont 28-31
measurements of, at Malta, Mont 26-28
Mill Creek, Texas, measurements of 156
Minnichaduza Creek, Nebraska, measurements of 49
Missouri River, measurements of, at Cascade, Mont 35-36
measurements of, at Townsend, Mont.. 36-38
stream measurements in basin of..... 13-50
Mitchell, Nebr., stream measurements at .. 66-68
Moorhead, Tex., stream measurements near 166-168
Morrison, Colo., stream measurements at .. 94
stream measurements near..... 89
Mount Princeton, Colo., stream measurements at 138
Musselshell River, Montana, measurements of 31-32
Naples, Tex., stream measurements near .. 140
Neches River, Texas, measurements of 142
stream measurements in basin of..... 141-142
Neosho River, Kansas, measurements of. 115-116
Nepesta, Colo., stream measurements near 128-130
New Braunfels, Tex., stream measurements near..... 157
Newell, Colo., stream measurements at 138
Niles, Kans., stream measurements at..... 105-107
Niobrara, Nebr., stream measurements at.. 16-17
Niobrara River, measurements of, at Niobrara, Nebr..... 16-17
measurements of, at Valentine, Nebr.. 18-20
miscellaneous 49
Norfolk, Nebr., stream measurements at... 92
stream measurements near..... 53-55
North Loup River, Nebraska, measurements of..... 92
North Platte, Nebr., stream measurements at..... 62-64, 93
North Platte River, measurements of, at Bridgeport, Nebr..... 64-66
measurements of, at Guernsey, Wyo... 68-70
at Mitchell, Nebr..... 66-68
at North Platte, Nebr..... 62-64
miscellaneous 92
North Platte River, Wyoming, measurements of, miscellaneous..... 94
North Turkey Creek, Colorado, measurements of..... 94
Noyes Ditch, Texas, measurements of..... 156
Ottawa, Kans., stream measurements at... 14-15
Ouachita River, Arkansas, measurements of 140
Oxford, Nebr., stream measurements at. 112-113
Oxford Farmers' Canal, Colorado, measurements of..... 129
Pass Creek, Wyoming, measurements of... 94
Pecos, Tex., stream measurements near.. 168-172
Pecos River, measurements of, near Moorhead, Tex 166-168
measurements of, near Pecos, Tex... 168-172
Piney Creek, Wyoming, measurements of.. 21
Pittsburg, Tex., stream measurements near. 140
Platte River, measurements of, at Kearney, Nebr..... 92
Platte River, measurements of, near Columbus, Nebr 57-59
measurements of, near Lexington, Nebr. 59-61
stream measurements in basin of 50-94
Prairie Lea, Tex., stream measurements at. 157
Presidio, Tex., stream measurements above..... 177-179
Presidio, Tex., stream measurements below..... 175-177
Pueblo, Colo., stream measurements at .. 130-133
Radersburg, Mont., stream measurements at 50
Red River, Arkansas, measurements of 140
stream measurements in basin of..... 139-140
Redbluff, Mont., stream measurements near 46-47
Reis Springs, Wyo., stream measurements at 94
Republican River, measurements of, at Junction, Kans..... 100-102
measurements of, near Superior, Nebr. 102-105
miscellaneous 112-113
Richmond, Tex., stream measurements at. 147
Rio Grande, N. Mex., stream measurements near 186-189
Rio Grande River, measurements of, above Presidio, Tex 177-179
measurements of, at Eagle Pass, Tex. 158-160
at Embudo, N. Mex 189-192
at Langtry, Tex 172-174
below Presidio, Tex 175-177
near Cenicero, Colo 192-194
near Del Norte, Colo 194-196
near Devils River, Texas 161-163
near El Paso, Tex..... 181-183
near Port Hancock, Tex..... 179-180
near Rio Grande, N. Mex..... 186-189
near San Marcial, N. Mex..... 183-186
stream measurements in basin of..... 157-196
Riverside, Tex., stream measurements at. 142-143
Rock Creek, Nebraska, measurements of... 113
Rockyford, Colo., stream measurements near 126-127
Sabine River, Texas, measurements of..... 141
stream measurements in basin of..... 140-141
St. Paul, Nebr., stream measurements at... 92
St. Vrain Creek, Colorado, measurements of..... 81-84
Salado, Tex., stream measurements at..... 148
Salado River, Texas, measurements of..... 148
Salesville, Mont., stream measurements near 40-43
Salida, Colo., stream measurements at... 136-138
Salina, Kans., stream measurements near. 108-110
Saline River, Kansas, measurements of.. 108-110
Salt Creek, Nebraska, measurements of 93
San Antonio, Tex., stream measurements at. 157
San Antonio River, Texas, measurements of..... 157
San Felipe Creek, Texas, measurements of. 161
San Gabriel River, Texas, measurements of..... 148
San Marcial, N. Mex., stream measurements near 183-186
San Marcos River, Texas, measurements of..... 157
San Saba, Tex., stream measurements at... 156
San Saba River, Texas, measurements of. 154-156
Sand Creek, Nebraska, measurements of ... 93

Page.
Sappington, Mont., stream measurements at..... 47–49
Saratoga, Wyo., stream measurements at... 94
Segovia, Tex., stream measurements near.. 154
Seminole Mountains, Wyoming, stream measurements near 94
Seward, Nebr., stream measurements at.... 112
Shawmut, Mont., stream measurements at. 31–32
Shelby, Mont., stream measurements near. 32–34
Shoshone River, Wyoming, measurements of..... 21–23
Simmons, Wyo., stream measurements at.. 94
Sioux Falls, S. Dak., stream measurements at..... 49
Smoky Hill River, Kansas, measurements of..... 110–112
Splitrock, Wyo., stream measurements near 72
Spring Creek, Nebraska, measurements of. 93
Solomon River, Kansas, measurements of. 105–107
South Platte, Colo., stream measurements at 89–92
South Platte River, Colorado, measurements of, at Bigspring, Nebr 72–73
measurements of, at Denver, Colo..... 86–88
at Julesburg, Colo 73–75
at Kersey, Colo 77–79
at North Platte, Nebr..... 93
at South Platte, Colo 89–92
miscellaneous 94
Stratton, Nebr., stream measurements at... 112
Stubbs Ferry, Mont., stream measurements at..... 37
Sulphur Fork Creek, Texas, measurements of..... 140
Superior, Nebr., stream measurements near 102–105
Sweetwater River, Wyoming, measurements of..... 71

Page.
Syracuse, Kans., stream measurements at. 122–125
Tarryall Creek, Colorado, measurements of. 91
Thermopolis, Wyo., stream measurements near 22–24
Toston, Mont., stream measurements at.... 37
Townsend, Mont., stream measurements at. 36–38
Trinity River, Texas, measurements of .. 142–143
stream measurements in basin of 142–143
Trout Creek, Colorado, measurements of... 128
Two Medicine Creek, Montana, measurements of..... 34–35
Valentine, Nebr., stream measurements at..... 18–20, 49
Verdigris River, Kansas, measurements of 116–118
Waco, Tex., stream measurements at 143–146
Walhalla, Tex., stream measurements near. 157
Walnut River, Kansas, measurements of... 119
Washita River, Oklahoma, measurements of..... 139–140
Watertown, S. Dak., stream measurements near 15–16
Webster, Colo., stream measurements at... 94
West Gallatin River, Montana, measurements of..... 40–42
West Valley Ditch, Texas, measurements of..... 168–172
Westerfield Ford, Tex., stream measurements at..... 157
White River, Nebraska, measurements of, miscellaneous 49
White Tail Creek, Nebraska, measurements of..... 93
Winston, Colo., stream measurements at... 94
Wood River, Nebraska, measurements of .. 93
Wymore, Nebr., stream measurements at .. 112
Yellowstone River, Montana, measurements of..... 24–26

O

Water-Supply and Irrigation Paper No. 85 Series P, Hydrographic Progress Reports, 23

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

REPORT

OF

PROGRESS OF STREAM MEASUREMENTS

FOR

THE CALENDAR YEAR 1902

BY

F. H. NEWELL

PART IV.—INTERIOR BASIN, PACIFIC COAST, AND HUDSON BAY DRAINAGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

CONTENTS.

	Page.
Letter of transmittal	9
Introduction	11
Acknowledgments	14
Colorado River drainage basin	15
Colorado River at Yuma, Ariz	17
Colorado River at Bulls Head, Ariz	20
Verde River near McDowell, Ariz	21
Salt River at McDowell, Ariz	23
Salt River at reservoir site below Tonto Creek, near Livingstone, Ariz	25
Tonto Creek near Livingstone, Ariz	29
Gila River at San Carlos, Ariz	32
Animas River at Durango, Colo	35
Florida River near Durango, Colo	37
Los Pinos River at Ignacio, Colo	39
Dolores River at Dolores, Colo	41
Gunnison River at Whitewater, Colo	42
Gunnison River at Iola, Colo	44
Grand River near Palisades, Colo	46
Grand River at Glenwood Springs, Colo	48
White River at Meeker, Colo	50
Uinta River at Ouray School, near Leland, Utah	52
Duchesne River at Price Road bridge, Utah	55
Lake Creek at wagon bridge (near mouth), Utah	58
Uinta River at Fort Duchesne, Utah	61
Uinta River near Whiterocks, Utah	65
Whiterocks River near Whiterocks, Utah	68
Ashley Creek near Vernal, Utah	71
Yampa River at Craig, Colo	74
Green River at Greenriver, Wyo	75
Miscellaneous measurements in the Colorado River drainage basin	77
Interior Basin	78
Bear River near Collinston, Utah	80
Bear River at Battlecreek, near Preston, Idaho	82
Blacksmith Fork at Hyrum, Utah	84
Logan River near Logan, Utah	86
Weber River near Uinta, Utah	87
Provo River near Provo, Utah	88
Sevier River at Gunnison, Utah	88
San Pitch River near Gunnison, Utah	94
Humboldt River near Oreana, Nev	96
Humboldt River near Golconda, Nev	98
Humboldt River at Palisade, Nev	100
Pine Creek at Palisade, Nev	101

Interior Basin—Continued.
Humboldt River (South Fork) at Mason's ranch, near Elko, Nev
Humbolt River near Elko, Nev
Humboldt River (North Fork) near Halleck, Nev
Marys River at Bradley's home ranch, near Deeth, Nev
Walker River near Wabuska, Nev
Walker River (East Fork) at Ross ranch, near Yerington, Nev
Walker River (West Fork) at upper end of Antelope Valley, near Coleville, Cal
Carson River near Empire, Nev
Carson River (East Fork) at Rodenbah's ranch, near Gardnerville, Nev
Carson River (West Fork) at Woodfords, Cal
Truckee River at Tahoe, Cal
Truckee River at Vista, Nev
Truckee River near Mystic, at Nevada-California State line
Independence Creek below Independence Lake, near Overton, Cal
Prosser Creek below Prosser Creek Ice Company's dam, near Boca, Cal
Donner Creek near Donner Ice Company's dam, near Truckee, Cal
Susan River near Susansville, Cal
Miscellaneous measurements in the Interior Basin
San Francisco Bay drainage basin
Cache Creek at Lower Lake, Cal
Feather River at Oroville, Cal
Stony Creek at Julian's ranch, near Fruto, Cal
Sacramento River at Jellys Ferry and at Iron Canyon, near Red Bluff, Cal
Tuolumne River and Turlock Canal at Lagrange, Cal
Merced River above Merced Falls, Cal
King River at Kingsburg, Cal
King River at Red Mountain, near Sanger, Cal
Tule River near Portersville, Cal
Kern River near Bakersfield, Cal
San Joaquin River at Herndon, Cal
Miscellaneous measurements in the San Francisco Bay drainage basin
Southern California drainage
Arroyo Seco at Pettitt's ranch, near Soledad, Monterey County, Cal
San Lorenzo Creek near King City, Cal
San Gabriel River and Canals at Azusa, Cal
Santa Ana River below Warmsprings, Cal
Mohave River at Victorville, Cal
Miscellaneous measurements in Southern California drainage
Columbia River drainage basin
Umatilla River at Gibbon, Oreg
Yakima River at Kiona, Wash
Yakima River at Union Gap, Wash
Naches River near North Yakima, Wash
Tieton River near North Yakima, Wash
Spokane River at Spokane, Wash
Missoula River at Missoula, Mont
Bitterroot River near Grantsdale, Mont
Palouse River near Hooper, Wash
Weiser River near Weiser, Idaho
Boise River near Boise, Idaho
Seepage measurements in Boise Valley, Idaho

Columbia River drainage basin—Continued. Page.
Bruneau River near Grandview, Idaho 212
Snake River at Montgomery Ferry, near Minidoka, Idaho 213
Snake River (North Fork) near Ora, Idaho 215
Fall River near Marysville, Idaho 215
Miscellaneous measurements in the Columbia River drainage basin 216
Puget Sound drainage basin 216
White River at Buckley, Wash 217
Cedar River near Maple Valley, Wash 218
Cedar River at Cedar Lake, near Northbend, Wash 220
Snoqualmie River above Snoqualmie Falls, near Snoqualmie, Wash 220
Skykomish River (South Fork) near Index, Wash 222
Stilaguamish River near Robe, Wash 223
Hudson Bay drainage basin 224
St. Mary River at international line near Cardston, Alberta 225
St. Mary River at Main, Mont 226
Swiftcurrent Creek at Henkel's ranch near St. Mary, Mont 229
St. Mary River at dam site near St. Mary, Mont 231
Red River at Emerson, Manitoba 233
Red Lake River at Crookston, Minn 234
Red River at Grand Forks, N. Dak 235
Sheyenne River at Haggart, N. Dak 236
Red River at Fargo, N. Dak 237
Devils Lake at Devils Lake, N. Dak 238
Index 241

ILLUSTRATIONS.

Page.

FIG. 1. Location of river stations and principal irrigation projects in western half of United States, 1902–3 12

2. Location of river stations in eastern half of United States, 1902–3 13

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 29, 1903.

SIR: I have the honor to transmit herewith Water-Supply Paper No. 85, which is Part IV of and completes the report of progress of stream measurements for the year 1902. This paper contains the data which has been received during 1902 from that portion of the territory west of the Mississippi River which does not drain into either the Mississippi River or the western Gulf of Mexico.

This paper contains for the various gaging stations the original data as collected and the results obtained from the discussion of this data, also such other information as is of interest in hydrographic studies.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PROGRESS REPORT OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1902.

PART IV.

By F. H. NEWELL.

INTRODUCTION.

This paper contains data collected during 1902 from that portion of the territory west of Mississippi River which does not drain into either Mississippi River or the western Gulf of Mexico. It completes the Report of the Progress of Stream Measurements for the Year 1902, which report is made up of Water-Supply Papers Nos. 82–85, inclusive.

Water-Supply Papers Nos. 82 and 83 contain the data collected in the territory east of Mississippi River, and papers Nos. 84 and 85 that collected west of Mississippi River. The material in each of these papers consists of both the original data as collected at the various river stations and the results obtained from the discussion of these data; also brief descriptions and facts regarding such other subjects as are allied to hydrographic studies.

For convenience in arrangement the data in this paper have been grouped into the following drainage areas and arranged in the order given: Colorado River drainage, Interior Basin, San Francisco Bay drainage, Southern California drainage, Columbia River drainage, Puget Sound drainage, and Hudson Bay drainage.

On figs. 1 and 2 the dots show the locations of the stations at which the United States Geological Survey is collecting hydrographic data. The section west of the shaded line comprises those States which are covered by the national irrigation act of June 17, 1902 (32 Stat. L., 388–390), and the cross-lined areas show the location of the irrigation projects which are now under investigation.

In collecting hydrographic data the Geological Survey has received the hearty cooperation of various individuals, corporations, and States, as mentioned hereafter. This cooperation has made possible the pub-

lication of many valuable records, which could not otherw been obtained.

A brief historical sketch of the stream measurements mad United States Geological Survey is published on pages 11–15 o Supply Paper No. 75.

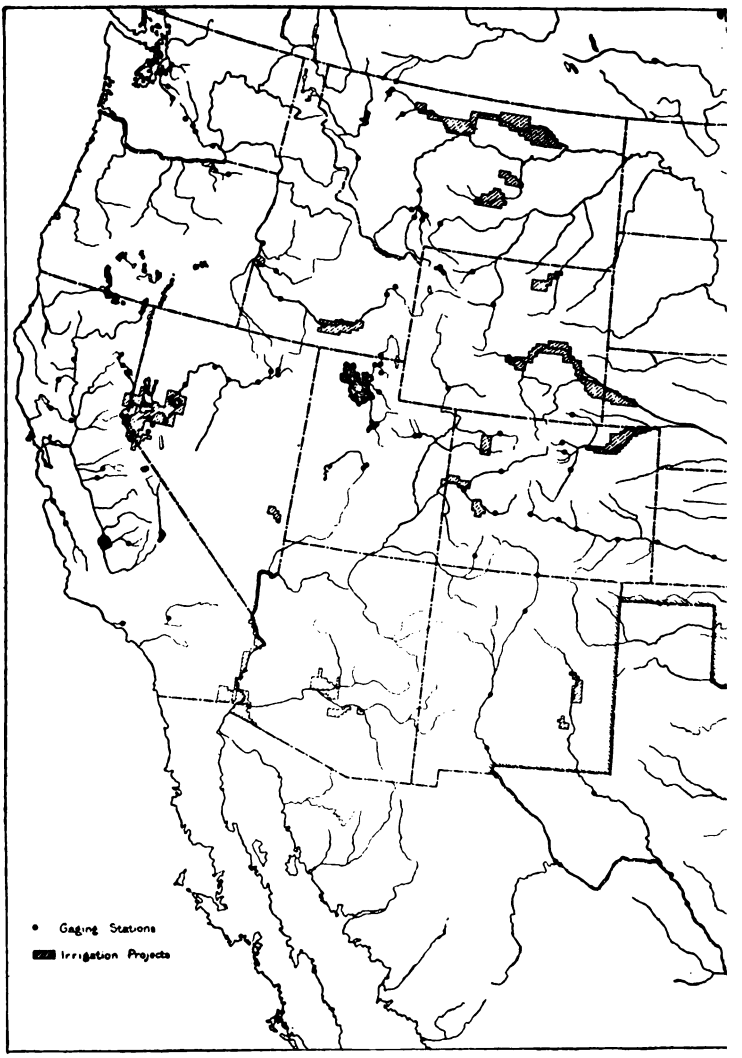


FIG. 1.—Location of river stations and principal irrigation projects in western hal States, 1902–3

The results of the stream measurements made during the p by the United States Geological Survey can be found in the f publications, which may be consulted at the public libraries of our cities:

1893. Bulletin No. 131.
1894. Bulletin No. 131.

5. Bulletin No. 140.
6. Water Supply Paper No. 11, Part IV of the Eighteenth Annual Report.
7. Water Supply Papers Nos. 15 and 16, Part IV of the Nineteenth Annual Report.
8. Water Supply Papers Nos. 27 and 28, Part IV of the Twentieth Annual Report.

FIG. 2.—Location of river stations in eastern half of United States, 1902-3.

1899. Water Supply Papers Nos. 35 to 39, inclusive, Part IV of the Twenty Annual Report.
1900. Water Supply Papers Nos. 47 to 52, inclusive, Part IV of the Tv second Annual Report.
1901. Water Supply Papers Nos. 65, 66, and 75.
1902. Water Supply Papers Nos. 82 to 85, inclusive.

ACKNOWLEDGMENTS.

Most of the measurements presented in this paper have been obtained through local hydrographers and engineers. Acknowledgment is due to each of these persons, and thanks are extended to other persons and corporations who have assisted local hydrographers, or who have cooperated in any way, either by furnishing records or by assisting in transportation.

The following list, arranged alphabetically by States, gives the names of the resident hydrographers and others who have assisted in furnishing and preparing the data contained in this report:

Arizona.—The data on Colorado River were collected by J. B. Lippincott and his assistant. That upon the Salt and Gila rivers and Tonto Creek by Stephen Janus and Osburn Richins.

California.—Resident hydrographers, J. B. Lippincott, assisted by Samuel G. Bennett, and L. H. Taylor, assisted by E. C. Murphy and D. W. Hays. Acknowledgments are also due to the following individuals and corporations for assistance rendered and data furnished: To H. F. Parkinson, water overseer for the irrigators in the vicinity of Azusa, Cal., for voluntary observations on San Gabriel River and canals; the Kern County Land Company, through its chief engineer, Walter James, and engineer in charge of water measurements, A. K. Warren, for the record of Kern River; the Southern Pacific Company, through its chief engineer, William Hood, for river stage records of San Joaquin River at Herndon, Cal., and the King River at Kingsburg, also for transportation furnished the resident hydrographers and assistants; to the officials of the Santa Fe Route and Lake Tahoe Railway and Transportation Company for transportation of the resident hydrographers and assistants.

Colorado.—Resident hydrographer, A. L. Fellows, assisted by M. C. Hinderlider. Acknowledgments for assistance rendered and data furnished are due to Hon. A. J. McCune, State engineer of irrigation; A. F. Reeves, superintendent of irrigation, and to various water commissioners who are located in this division and who have given their assistance from time to time. Transportation has been furnished by the Denver and Rio Grande; Atchison, Topeka and Santa Fe; Colorado and Southern, and Rio Grande Southern railroads. Special assistance was also rendered by William H. Richardson at Glenwood Springs.

Idaho.—Resident hydrographer, N. S. Dils. Acknowledgments are due to the Oregon Short Line Railway Company for transportation furnished N. S. Dils.

Minnesota.—The data from this State were collected by the late C. M. Hall.

Montana.—Resident hydrographer, J. S. Baker, assisted by H. B. Waters.

Nevada.—Resident hydrographer, L. H. Taylor, assisted by E. C. Murphy and D. W. Hays. Acknowledgments are also due to the Southern Pacific Railroad Company and Lake Tahoe Railway and Transportation Company for transportation furnished.

North Dakota.—The data from this State were collected by the late C. M. Hall.

Oregon.—Resident hydrographer, Sydney Arnold.

Utah.—Resident hydrographers, Howard S. Reed and George L. Swendsen, assisted by W. D. Beers, Caleb Tanner, and W. G. Swendsen. Acknowledgments for assistance rendered and data furnished are due to the Utah Light and Power Company, Ogden, Utah; the Hercules Power Company, Logan, Utah, and the Bear River Canal Company, Corinne, Utah.

Washington.—Resident hydrographers, T. A. Noble, assisted by H. W. Quinan; and Sydney Arnold. Acknowledgments are also due to the following individuals

for assistance rendered and data furnished: To Reginald H. Thomson, city engineer of Seattle, Wash.; to Louis G. Heybrock, who has been voluntary observer at the station of the south fork of Skykomish River, and to A. A. Batcheller, who has been voluntary observer at the station on Cedar River at Cedar Lake, and to James J. Hill, who has furnished transportation to the resident hydrographer in the State of Washington over the Great Northern Railway. Transportation has been furnished to Sydney Arnold by Thomas Cooper, general manager of the Northern Pacific Railway, thus greatly facilitating the extension of the field work.

Wyoming.—Resident hydrographer, A. J. Parshall. Acknowledgments are also due to H. G. Burt, president of Union Pacific Railroad Company, for transportation furnished over its lines in Wyoming to the resident hydrographer.

COLORADO RIVER DRAINAGE BASIN.

Topographically considered, this is the largest hydrographic basin lying wholly within the arid region, having a total area above the town of Yuma, Ariz., of over 225,000 square miles.

This basin is situated in Wyoming, Utah, Colorado, Arizona, New Mexico, Nevada, and California, but the principal water supply comes from the melting snows of the high mountains of Wyoming, Utah, and Colorado. The minimum flow is less than 3,000 cubic feet per second. The maximum reaches more than 50,000 cubic feet per second.

This stream has been called the Nile of America. Like the Nile, the Colorado is subject to an annual summer rise, which comes at a time when it is most needed for irrigation. Its waters carry a large amount of sediment, reaching as high as 2,000 parts of sediment to 100,000 parts of water. The minimum amount is carried during the winter months and probably is never less than 60 parts of sediment to 100,000 parts of water.

Prof. R. H. Forbes, in Bulletin No. 44, University of Arizona Agricultural Experiment Station, says:

> On the basis of the profile constructed from available data for the volume of flow of the Colorado, and of the year's silt determinations made in this laboratory, it is estimated conservatively that the river during 1900 brought down about 61,000,000 tons of sedimentary material, which, condensed to the form of solid rock, is enough to cover 26.4 square miles 1 foot deep, or to make 53 square miles of dry, alluvial soil 1 foot deep, or to make about 164 square miles of recently settled, submerged mud 1 foot deep, reckoning the whole amount of mud for the year to average 6.2 times the bulk of the solid sediment.

Comparatively a small amount of land is irrigated by the waters of Colorado River, owing to the fact that the main stream and both of its tributaries are situated so far below the level of the irrigable lands as to render their diversion extremely difficult or impracticable.

There are two pumping plants that lift water for irrigation at Yuma and several at other points on the river above Yuma. The Imperial canal diverts water at a point on the right bank of the river 6 miles below Yuma. It is the intention of the owners of this canal to reclaim a large tract of fertile land situated in Mexico and in California.

Discharge measurements of Colorado River at Yuma, Ariz.

Date.	Hydrographer.	Gage height.	Disch
1902.		*Feet.*	*Sec.-*
January 9	J. B. Lippincott	17.20	[illegible]
February 20	S. G. Bennett	17.15	[illegible]
May 30	do	23.00	8[illegible]
July 7	W. W. Follett	21.06	1[illegible]
July 9	S. G. Bennett	20.52	1[illegible]
October 11	do	18.50	[illegible]
October 14	R. P. H. Laney	17.90	[illegible]
October 17	do	17.50	[illegible]
October 21	do	17.60	[illegible]
October 24	do	17.50	[illegible]
November 12	S. G. Bennett	17.40	[illegible]
November 13	do	17.50	[illegible]
November 15	W. D. Smith	18.55	[illegible]
November 18	do	18.05	[illegible]
November 20	do	18.00	[illegible]
November 22	do	18.10	[illegible]
November 24	do	18.45	[illegible]
November 26	do	18.40	[illegible]
November 28	do	18.50	[illegible]
December 1	do	20.00	1[illegible]
December 3	do	19.25	
December 5	do	18.85	
December 8	do	18.30	
December 10	do	18.20	
December 12	do	18.00	
December 15	do	17.65	
December 16	do	17.50	
December 18	do	18.30	
December 19	do	18.05	
December 20	do	18.05	
December 22	do	17.70	
December 24	do	18.00	
December 26	do	18.10	
December 27	do	18.30	
December 29	do	18.00	
December 31	do	17.70	

Daily gage height, in feet, of Colorado River at Yuma, Ariz.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	17.10	18.00	17.90	18.20	20.00	22.30	22.00	18.40	17.50	18.90	17.40	20.00
2	17.00	18.00	17.90	18.00	20.70	22.20	21.70	18.30	17.30	18.50	17.30	19.50
3	17.00	18.00	18.00	17.90	20.80	22.20	21.50	18.30	17.00	18.40	17.30	19.30
4	17.00	17.90	17.90	17.90	20.50	22.70	21.30	18.30	18.00	18.60	17.30	19.00
5	17.00	17.90	17.90	17.90	20.30	23.10	21.10	18.10	18.80	18.30	17.30	18.90
6	17.00	17.80	17.90	18.00	20.30	23.10	20.80	18.00	18.30	18.10	17.30	18.60
7	17.00	17.70	18.10	18.00	20.40	23.50	20.70	17.90	18.00	18.00	17.20	18.40
8	17.20	17.70	18.20	18.20	20.50	23.70	20.60	17.80	17.60	18.10	17.20	18.30
9	17.20	17.60	18.10	18.20	20.30	24.00	20.40	17.80	17.50	18.10	17.20	18.30
10	17.30	17.50	18.10	18.20	20.50	24.20	20.30	17.80	17.30	18.10	17.30	18.20
11	17.30	17.50	18.10	18.20	22.00	24.30	20.30	17.70	17.30	18.50	17.30	18.10
12	17.30	17.60	18.10	18.20	22.30	24.20	20.60	17.70	17.30	18.30	17.40	18.00
13	17.30	17.10	18.20	18.20	22.30	24.30	20.50	17.60	17.30	18.00	17.50	18.10
14	17.30	17.10	18.20	18.20	22.80	24.00	20.20	17.60	17.30	17.80	18.00	17.70
15	17.30	17.20	18.30	18.20	22.90	23.80	20.10	17.50	17.30	17.80	18.50	17.60
16	17.30	17.30	18.40	18.20	23.20	23.90	20.00	17.40	17.20	17.60	18.00	17.50
17	17.40	17.30	18.40	18.10	23.50	23.70	20.30	17.30	17.70	17.60	17.80	17.70
18	17.60	17.30	18.30	18.00	23.70	23.80	19.80	17.30	17.50	17.40	18.10	18.30
19	17.70	17.30	18.30	18.00	24.10	23.70	19.80	17.10	17.30	17.60	18.10	18.10
20	17.70	17.20	18.30	18.00	24.30	23.60	19.70	17.00	17.30	17.60	18.10	18.00
21	17.70	17.10	18.30	18.00	24.30	23.50	19.50	17.80	17.00	17.40	18.00	17.80
22	17.70	17.30	18.30	18.30	24.40	23.50	19.40	18.50	16.80	17.40	18.10	17.80
23	17.70	17.70	18.30	19.30	24.40	23.20	19.30	18.30	16.80	17.30	18.10	17.80
24	17.70	18.00	18.30	19.80	24.40	23.10	19.40	17.90	16.90	17.30	18.40	18.00
25	17.80	18.10	18.30	19.80	24.40	23.00	19.10	17.80	17.10	17.30	18.50	18.20
26	17.90	18.10	18.20	19.80	24.50	22.70	19.30	18.00	16.80	17.30	18.40	18.10
27	17.90	18.10	18.30	19.90	24.30	22.60	19.00	17.90	16.70	17.30	18.50	18.30
28	17.90	18.00	18.30	20.00	24.00	22.50	18.80	17.70	16.60	17.30	18.50	18.20
29	17.80	.....	18.30	19.80	23.50	22.30	18.50	17.30	17.50	17.20	18.50	18.00
30	18.00	.....	18.30	19.80	23.00	22.20	18.40	17.20	19.40	17.20	18.30	17.80
31	18.00	.....	18.30	.....	22.70	.....	18.30	17.20	.....	17.30	.....	17.70

Rating table for Colorado River at Yuma, Ariz., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
16.5	3,030	18.2	4,920	20.4	13,800	22.6	33,400
16.6	3,050	18.4	5,340	20.6	15,200	22.8	35,800
16.7	3,080	18.6	5,790	20.8	16,600	23.0	38,200
16.8	3,120	18.8	6,310	21.0	18,200	23.2	40,800
16.9	3,170	19.0	6,910	21.2	19,800	23.4	43,400
17.0	3,230	19.2	7,590	21.4	21,500	23.6	46,100
17.2	3,380	19.4	8,360	21.6	23,300	23.8	48,900
17.4	3,580	19.6	9,300	21.8	25,100	24.0	51,700
17.6	3,850	19.8	10,300	22.0	27,000	24.2	54,700
17.8	4,160	20.0	11,400	22.2	29,000	24.4	57,700
18.0	4,520	20.2	12,600	22.4	31,200	.....	.....

Estimated monthly discharge of Colorado River at Yuma, Ariz.

[Drainage area, 225,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	4.530	3.290	3.727	229.164	0.017	0.020
February	4.730	3.290	3.955	219.650	.018	.019
March	5.340	4.340	4.903	301.474	.022	.025
April	11.400	4.340	6.179	367.676	.027	.030
May	59.300	11.400	35.961	2,211.156	.160	.184
June	56.300	29.000	42.530	2,530.115	.189	.211
July	27.000	5.130	12.527	770.255	.056	.065
August	5.560	3.290	4.183	257.303	.019	.022
September	6.360	3.050	3.819	227.246	.017	.019
October	6.600	3.140	4.299	264.335	.019	.022
November	5.540	3.140	4.187	249.144	.019	.021
December	12.600	3.590	5.412	332.771	.024	.028
The year	59.200	3.050	10.973	7,960.189	.049	.666

COLORADO RIVER AT BULLS HEAD, ARIZ.

A gaging station was established at a point of rocks on Colorado River, known as the Bulls Head, by E. T. Perkins, engineer. The station is situated at the Bulls Head, 35 miles north of Needles, Cal., and is accessible only by wagon road up the Arizona side of the river. A cable was stretched across the river at this point on December 1, 1902. T. M. Whedbee, hydrographic aid, was assigned as observer. He resided at the engineering camp, which had headquarters at this locality.

The river was measured with a Price electric-current meter three times a week, and rod readings were taken daily. Mr. Whedbee is believed to be a reliable and accurate observer. The equipment consisted of a five-eighths-inch cable and a gaging car and tag wire. The station was maintained as long as the engineering camp remained at the Bulls Head, and then the material was removed and stored at the Needles, with the exception of the gage rod.

The gage is an inclined wooden rod divided into tenths of a foot. It is well painted and is fastened to the left rock bank of the river. A bronze bench-mark tablet is set on the Arizona side in the rock about 20 feet above low-water mark and about 50 feet downstream from the gage rod. The elevation of the bench mark is 530.523 feet

above sea level and the zero of the rod equals an elevation of 499.902 feet. The initial point for soundings is the left bank. The river channel is straight for about 1,000 feet above and 500 feet below the cable station and the current is rather swift. The banks are high and rocky, but the channel of the river is shifting silt. A determination was made of the value of "*n*" at this gaging station. It was found that "*n*" equaled 0.010.

Discharge measurements of Colorado River at Bulls Head.

Date.	Hydrographer	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
December 5	J. T. Whistler	3.00	5,786
December 10	L. M. Barnes	2.65	4,051
December 13	do	2.45	3,222
December 17	do	2.95	4,138
December 20	do	3.50	4,792
December 24	do	3.23	4,939
December 29	do	2.45	3,366
December 31	do	2.20	2,913

VERDE RIVER NEAR M'DOWELL, ARIZ.

A number of large irrigation enterprises have been planned, designed to divert water from the lower stretch of this river to irrigate lands north of Phœnix, but none has been constructed. The results of measurements of this river combined with those of Salt River show the amount of water available for the irrigable lands of Phœnix Valley. The dam of the Arizona Canal Company is located on Salt River immediately below the mouth of the Verde. The gaging station on the Verde is located three-fourths of a mile above its mouth and 30 miles northeast of Phœnix. It was established April 20, 1897. The station is equipped with a cable, car, and tagged wire. The gage consists of a 2 by 4 inch inclined rod fastened to posts driven into the east bank of the river about 400 feet below the gaging cable. The bench mark is on a cat's-claw tree (*Acacia*) about 100 feet southeast of the old gage, on a cottonwood tree, which is 60 feet below the cable. The elevation of the bench mark is 27.02 feet above gage datum. The channel of the river is similar to that of Salt River—sandy and liable to change during a slight rise, and a large number of measurements are necessary in order to accurately determine the discharge.

Discharge measurements of Verde River near McDowell, Ariz.

Date.	Hydrographer.	Gage height.	Disch
1903.		*Feet.*	*Secon*
January 4	J. Fred Appleby	5.33	
January 11	do	5.36	
January 19	do	5.29	
January 25	do	5.35	
January 27	do	5.41	
February 1	do	5.45	
February 8	do	5.35	
February 15	do	5.32	
February 22	do	5.31	
March 1	do	5.40	
March 8	W. Richins	5.40	
March 15	do	5.41	
March 22	do	5.35	
March 26	do	5.48	
March 29	do	5.50	
April 1	do	5.95	
April 5	do	5.52	
April 8	do	5.42	
April 10	do	5.50	
April 15	do	5.20	
April 19	do	5.10	
July 14	Frank P. Trott	4.47	
July 19	do	4.58	
July 26	do	5.00	

Daily gage height, in feet, of Verde River near McDowell, Ariz.

Day.	Jan.	Feb.	Mar.	Apr.	July.
1902.					
1	5.33	5.44	5.40	5.93	
2	5.34	5.43	5.42	5.93	
3	5.34	5.43	5.42	5.68	
4	5.33	5.40	5.43	5.63	
5	5.33	5.39	5.44	5.51	
6	5.33	5.39	5.42		
7	5.39	5.40	5.40	5.42	
8	5.35	5.34	5.40	5.44	
9	5.34	5.36	5.37	5.55	
10	5.32	5.38	5.40	5.49	
11	5.36	5.36	5.40	5.42	
12	5.35	5.35	5.47	5.39	
13	5.36	5.38	5.43		
14	5.35	5.38	5.42	5.27	
15	5.33	5.32	5.41	5.20	
16	5.29	5.32	5.41	5.17	
17	5.29	5.31	5.41	5.15	
18	5.29	5.33	5.41	5.11	
19	5.29	5.36	5.41	5.10	
20	5.31	5.34	5.40		
21	5.32	5.32	8.39		
22	5.33	5.31	5.35		
23	5.33	5.33			4.90
24	5.33	5.32	5.35		4.85
25	5.36	5.37	5.40		7.44
26	5.45	5.42	5.52		5.00
27	5.41	5.39	5.47		
28	5.38	5.36	5.49		
29	5.39		5.49		
30	5.45				
31	5.43		5.42		

SALT RIVER AT M'DOWELL, ARIZ.

Irrigation is practiced to a small extent on Salt River in what is known as Tonto Valley, but shortly after Tonto Creek joins it the river enters a canyon and continues in it until a short distance above the mouth of Verde River. At this point the river reappears from its canyon, and its course is thence across the Plains district until it enters Gila River at the northwest corner of Gila River Indian Reservation. From the mouth of Verde River down to Gila River a number of large canals divert the water of Salt River and serve the extensively irrigated lands in the vicinity of Phœnix on the north side and Mesa on the south side of the river. During ordinary seasons all of the water of Salt River is diverted, and at the present time there is a shortage in the summer months. The gaging station, established April 20, 1897, is located 4,000 feet above the mouth of the Verde and 30 miles northeast of Phœnix. The gage consists of a 2 by 6 inch scantling bolted to rocks on the south side of the river about 300 feet above the cable. The bench mark is a nail in a palo verde tree

about 75 feet west of the north cable anchorage and is 17.33 feet gage zero The bed of the river is sandy and shifting, and it is sary to make a large number of measurements in order to obt accurate estimate of the discharge.

The station was temporarily discontinued during 1900, but me ments were resumed in 1901.

Discharge measurements of Salt River at McDowell, Ariz.

Date.	Hydrographer.	Gage height.	Di
1902.		*Feet.*	*Sec*
January 4	J. Fred Appleby	0.82	
January 11	do	.79	
January 19	do	.82	
January 25	do	.85	
January 27	do	1.03	
February 1	do	.99	
February 8	do	.92	
February 15	do	.90	
February 22	do	.89	
March 1	do	.97	
March 8	W. Richins	.91	
March 15	do	.87	
March 22	do	.85	
March 26	do	1.02	
March 29	do	.96	
April 1	do	.92	
April 5	do	1.00	
April 8	do	1.12	
April 10	do	1.35	
April 15	do	1.26	
April 19	do	1.12	
July 14	F. P. Trott	.13	
July 19	do	.61	
December 24	W. Richins	1.30	

Daily gage height, in feet, of Salt River at McDowell, Ariz., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	Day.	Jan.	Feb.	Mar.	Apr.
1	0.79	0.99	0.96	0.91	17	0.82	0.91	0.88	1.19
2	.79	.97	.96	.91	18	.82	.90	.88	1.14
3	.79	.94	.94	.91	19	.81	.90	.85	1.12
4	.83	.91	.93	.93	20	.83	.89	.85	.....
5	.82	.90	92	.99	21	.83	.89	.85	.....
6	.81	.92	.92	1.03	22	.83	.89	.85	.....
7	.83	.93	.92	1.07	23	.83	.89	.89	.....
8	.81	.92	.91	1.14	24	.83	.89	.92	.....
9	.80	.92	.89	1.28	25	.85	.90	1.04	.....
10	.81	.91	.91	1.37	26	1.02	.93	1.01	.....
11	.78	.90	.88	1.40	27	1.03	.93	1.00	.....
12	.77	.90	.87	1.40	28	1.02	.96	.99	.....
13	.81	.90	.87	1.35	29	.98	.....	.96	.....
14	.81	.90	.87	1.30	30	1.06	.....	.93	.....
15	.81	.90	.87	1.24	31	1.03	.....	.90	.....
16	.81	.91	.88	1.21					

Estimated monthly discharge of Salt River at McDowell, Ariz.

[Drainage area, 6,260 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	250	137	176	10,816	0.028	0.032
February	231	193	198	11,020	.032	.033
March	250	174	197	12,131	.031	.036
April 1 to 19	.....	.....	287	10,816	.046	.032

SALT RIVER AT RESERVOIR SITE, NEAR LIVINGSTONE, ARIZ.

The station, established February 7, 1901, by H. G. Heisler, is 15 miles west of Livingstone, Ariz. The rod is on the left bank of the river at the upper end of the gorge. Gagings are made from a traveling car suspended from a cable.

Discharge measurements of Salt River at reservoir site near Livingstone, A

Date.	Hydrographer.	Gage height.	Discha
1902.		*Feet.*	*Second*
January 4	W. Richins	7.02	
January 8	do	7.00	
January 11	do	6.98	
January 14	do	7.03	
January 17	do	7.01	
January 20	do	7.02	
January 24	do	7.02	
January 27	do	7.19	
January 31	do	7.13	
February 4	Osburn Richins	7.09	
February 7	do	7.10	
February 11	do	7.09	
February 14	do	7.10	
February 18	do	7.09	
February 21	do	7.09	
February 25	do	7.10	
February 28	do	7.19	
March 4	do	7.13	
March 7	do	7.09	
March 11	do	7.12	
March 14	do	7.09	
March 19	do	6.90	
March 21	do	6.92	
March 25	do	7.20	
March 28	do	7.17	
April 4	do	7.24	
April 7	do	7.30	
April 10	do	7.51	
April 14	do	7.41	
April 18	do	7.30	
April 21	do	7.23	
April 25	do	7.19	
April 30	do	6.98	
May 5	do	6.89	
May 8	do	6.90	
May 13	do	6.80	
May 15	do	6.80	
May 19	do	7.47	
May 23	do	6.92	

Discharge measurements of Salt River at reservoir site near Livingstone, Ariz.—Continued.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
May 27	Osburn Richins	7.29	256
June 2	do	7.09	189
June 6	do	6.89	148
June 10	do	6.71	98
June 14	do	6.64	91
June 26	do	6.48	91
June 29	do	6.45	86
June 30	do	6.58	70
July 6	do	6.41	80
July 12	do	6.35	69
July 18	do	6.84	150
July 23	do	6.65	106
July 31	do	6.40	79
August 4	do	7.04	90
August 8	do	7.59	373
August 9	do	7.85	657
August 11	do	8.96	2,401
August 18	do	7.00	187
August 24	do	7.84	541
September 1	do	6.91	125
September 5	do	8.05	798
September 11	do	7.10	212
September 18	do	7.00	178
September 19	do	8.65	2,045
September 20	do	9.30	3,943
October 6	do	6.81	149
October 13	do	6.80	147
October 27	do	6.80	139
November 7	do	6.81	145
November 13	do	7.55	478
November 20	do	6.92	188
November 23	do	7.23	344
December 2	do	6.90	191
December 13	do	8.10	774
December 14	do	9.00	2,477
December 29	do	7.21	317

Daily gage height, in feet, of Salt River at the reservoir site near Livingstone, Ariz.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	6.99	7.13	7.19	7.12	6.83	7.10	6.44	6.37	6.91	7.04	6.81	6.9[illegible]
2	6.98	7.12	7.14	7.12	6.48	7.65	6.43	6.35	6.86	7.00	6.81	6.9[illegible]
3	7.01	7.10	7.15	7.19	6.55	6.98	6.42	7.23	6.83	6.91	6.81	6.9[illegible]
4	7.02	7.09	7.13	7.24	6.80	6.92	6.42	6.95	6.80	6.86	6.81	6.9[illegible]
5	7.01	7.10	7.13	7.24	6.89	6.90	6.42	6.43	7.85	6.81	6.81	6.9[illegible]
6	7.01	7.10	7.12	7.29	6.87	6.87	6.41	6.90	7.30	6.81	6.81	6.90
7	7.01	7.11	7.10	7.32	6.89	6.82	6.40	7.38	7.25	6.81	6.81	6.90
8	7.00	7.11	7.09	7.43	6.90	6.80	6.40	7.85	6.93	6.80	6.81	6.90
9	7.00	7.11	7.13	7.51	6.88	6.80	6.38	7.58	6.90	6.80	6.81	6.90
10	6.99	7.11	7.11	7.51	6.83	6.73	6.36	7.43	7.10	6.80	6.83	6.92
11	6.98	7.11	7.05	7.50	6.81	6.71	6.36	8.55	7.16	6.80	6.95	6.92
12	7.01	7.11	7.11	7.47	6.81	6.68	6.35	9.68	7.07	6.80	7.37	6.92
13	7.03	7.11	7.11	7.47	6.80	6.66	6.33	7.90	6.99	6.80	7.50	8.80
14	7.04	7.11	7.09	7.39	6.80	6.65	6.31	7.30	6.98	6.80	7.12	8.95
15	7.01	7.10	7.09	7.38	6.80	6.65	6.31	7.23	7.14	6.78	7.09	8.45
16	7.02	7.10	7.11	7.31	6.80	6.64	6.41	7.17	7.08	6.78	7.00	7.95
17	7.01	7.10	7.10	7.31	6.80	6.64	6.45	7.05	7.03	6.78	6.99	7.55
18	7.01	7.09	6.65	7.29	6.83	6.62	6.78	6.98	7.00	6.79	6.94	7.42
19	7.02	7.10	6.85	7.29	7.30	6.60	6.62	6.94	7.75	6.80	6.92	7.42
20	7.02	7.10	6.94	7.25	7.00	6.58	6.60	6.90	9.50	6.80	6.92	7.60
21	7.03	7.10	6.91	7.23	6.97	6.54	6.58	6.83	9.59	6.80	7.66	7.52
22	7.03	7.10	6.99	7.22	6.95	6.52	6.56	6.80	9.46	6.80	7.64	7.48
23	7.02	7.10	7.06	7.22	6.93	6.51	6.67	6.77	9.29	6.80	7.26	7.38
24	7.02	7.11	7.17	7.21	7.02	6.49	6.97	8.32	9.13	6.80	7.12	7.28
25	7.09	7.10	7.20	7.19	7.19	6.49	6.79	7.95	9.00	6.80	7.10	7.24
26	7.20	7.13	7.20	7.19	7.25	6.48	6.84	7.56	8.75	6.80	7.02	7.20
27	7.19	7.20	7.19	7.19	7.29	6.46	6.76	7.40	8.43	6.80	6.99	7.20
28	7.13	7.18	7.15	7.18	7.29	6.45	6.73	7.27	7.75	6.80	6.98	7.20
29	7.14	.....	7.12	7.09	7.30	6.45	6.63	7.11	7.35	6.80	6.95	7.2[illegible]
30	7.18	.....	7.12	6.97	7.19	6.44	6.51	7.07	7.15	6.81	6.94	7.1[illegible]
31	7.13	.....	7.11	.....	7.14	.....	6.40	6.97	.....	6.81	.....	7.1[illegible]

Rating table for Salt River at reservoir site near Livingstone, Ariz., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
6.2	33	7.1	204	8.0	765	8.9	2,675
6.3	45	7.2	236	8.1	915	9.0	2,925
6.4	58	7.3	272	8.2	1,090	9.1	3,175
6.5	72	7.4	310	8.3	1,290	9.2	3,425
6.6	88	7.5	350	8.4	1,500	9.3	3,675
6.7	106	7.6	400	8.5	1,715	9.4	3,925
6.8	126	7.7	462	8.6	1,940	9.5	4,175
6.9	150	7.8	540	8.7	2,175	.....	.....
7.0	176	7.9	640	8.8	2,425	.....	.....

Estimated monthly discharge of Salt River at reservoir site near Livingstone, Ariz.

[Drainage area, 5,756 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	236	176	189	11,621	0.033	0.038
February	236	204	207	11,496	.036	.037
March	236	97	201	12,359	.035	.040
April	350	163	268	15,947	.047	.052
May	272	72	167	10,268	.029	.033
June	204	65	106	6,307	.018	.020
July	163	45	78	4,796	.014	.016
August	4,675	52	478	29,391	.083	.096
September	4,425	138	1,057	62,896	.184	.205
October	190	126	131	8,055	.023	.027
November	431	126	189	11,246	.033	.037
December	2,800	150	441	27,116	.077	.089
The year	4,675	45	293	211,498	.051	.690

TONTO CREEK NEAR LIVINGSTONE, ARIZ.

The station, established April 1, 1901, by H. G. Heisler, is 15 miles west of Livingstone, Ariz. It is about half a mile above the mouth. The gage is a vertical rod nailed to a cliff of cemented gravel on the left bank.

Discharge measurements of Tonto Creek near Livingstone, Ariz.

Date.	Hydrographer.	Gage height.	Disch
1902.		*Feet.*	*Second*
January 4	W. Richins	2.90	
January 17	do	2.90	
January 24	do	2.90	
January 27	do	2.95	
February 4	O. Richins	2.95	
February 7	do	2.95	
February 11	do	2.95	
February 14	do	2.95	
February 18	do	2.95	
February 21	do	2.95	
February 25	do	2.93	
February 28	do	2.95	
March 4	do	2.94	
March 7	do	2.94	
March 11	do	2.95	
March 14	do	2.91	
March 19	do	2.92	
March 21	do	2.90	
March 28	do	2.91	
April 4	do	2.91	
April 7	do	2.91	
April 14	do	2.91	
April 25	do	2.91	
May 5	do	2.91	
May 19	do	4.05	
August 6	do	3.70	
August 8	do	3.50	
August 11	do	4.00	
August 24	do	4.35	
September 5	do	3.51	
September 19	do	4.70	
November 13	do	3.90	
November 21	do	4.82	
November 23	do	3.78	
December 13	do	4.90	
December 14	do	5.30	
December 29	do	3.20	

Daily gage height, in feet, of Tonto Creek near Livingstone, Ariz.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.90	2.95	2.95	2.91	2.91	2.90	2.90	2.90	2.90	2.90	2.90	3.10
2	2.90	2.95	2.95	2.91	2.91	2.90	2.90	2.90	2.90	2.90	2.90	3.10
3	2.90	2.95	2.95	2.91	2.91	2.90	2.90	3.14	2.90	2.90	2.90	3.10
4	2.90	2.95	2.94	2.91	2.91	2.90	2.90	3.00	2.90	2.90	2.90	3.08
5	2.90	2.95	2.94	2.91	2.91	2.90	2.90	2.97	2.90	2.90	2.90	3.07
6	2.90	2.95	2.94	2.91	2.91	2.90	2.90	3.48	2.90	2.90	2.90	3.05
7	2.90	2.95	2.94	2.91	2.91	2.90	2.90	3.00	2.94	2.90	2.90	3.00
8	2.90	2.95	2.94	2.91	2.91	2.90	2.90	4.28	2.92	2.90	2.90	2.95
9	2.90	2.95	2.95	2.91	2.91	2.90	2.90	4.10	2.90	2.90	2.90	2.93
10	2.90	2.95	2.95	2.91	2.91	2.90	2.90	4.30	2.90	2.90	2.90	2.92
11	2.90	2.95	2.95	2.91	2.91	2.90	2.90	3.90	3.05	2.90	3.20	2.92
12	2.90	2.95	2.95	2.91	2.91	2.90	2.90	4.95	2.95	2.90	3.57	2.92
13	2.90	2.95	2.95	2.91	2.91	2.90	2.90	4.40	2.93	2.90	3.85	5.15
14	2.90	2.95	2.91	2.91	2.91	2.90	2.90	3.75	2.90	2.90	3.36	5.20
15	2.90	2.95	2.94	2.91	2.91	2.90	2.90	3.28	3.10	2.90	3.19	4.55
16	2.90	2.85	2.94	2.91	2.91	2.90	2.90	3.00	3.05	2.90	3.07	4.10
17	2.90	2.95	2.94	2.91	2.91	2.90	2.90	2.95	2.98	2.90	2.98	3.90
18	2.90	2.95	2.92	2.91	2.91	2.90	2.90	2.95	2.95	2.90	2.94	3.95
19	2.90	2.95	2.92	2.91	3.61	2.90	2.90	2.93	4.88	2.90	2.92	4.25
20	2.90	2.95	2.92	2.91	2.98	2.90	2.90	2.90	6.45	2.90	2.92	4.10
21	2.90	2.95	2.90	2.91	2.95	2.90	3.53	2.90	5.10	2.90	4.79	3.78
22	2.90	2.95	2.90	2.91	2.95	2.90	5.50	2.90	4.52	2.90	4.58	3.68
23	2.90	2.95	2.90	2.91	2.90	2.90	2.90	2.90	3.90	2.90	3.68	3.55
24	2.90	2.96	2.90	2.91	2.90	2.90	2.90	4.10	3.37	2.90	3.48	3.35
25	2.93	2.93	2.92	2.91	2.90	2.90	2.90	3.90	3.10	2.90	3.44	3.28
26	2.95	2.95	2.91	2.91	2.90	2.90	3.15	3.96	2.97	2.90	3.30	3.24
27	2.95	2.95	2.91	2.91	2.90	2.90	2.90	3.30	2.95	2.90	3.29	3.18
28	2.95	2.95	2.91	2.91	2.90	2.90	2.90	3.10	2.93	2.90	3.25	3.19
29	3.00	.....	2.91	2.91	2.90	2.90	2.90	2.99	2.90	2.90	3.22	3.20
30	3.00	.....	2.91	2.91	2.90	2.90	2.90	2.94	2.90	2.90	3.10	3.10
31	3.00	.....	2.91	.....	2.90	.....	2.90	2.91	.....	2.90	.....	3.00

Estimated monthly discharge of Tonto Creek near Livingstone, Ariz.

[Drainage area, 1,080 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep inc
1902.						
January	8.0	2.7	3.3	200	0.003	(
February	4.0	2.5	3.0	168	.003	
March	2.8	2.3	2.6	159	.002	
April	2.6	2.6	2.6	152	.002	
May	116.0	2.4	6.3	387	.006	
June	2.4	2.4	2.4	146	.002	
July	1,708.0	2.4	42.2	2,597	.041	
August	1,158.0	2.4	143.7	8,837	.139	
September	1,308.0	2.4	138.8	8,258	.134	
October	2.4	2.4	2.4	151	.002	
November	1,008.0	2.4	93.8	5,583	.091	
December	1,408.0	2.6	188.4	11,582	.182	
The year	1,708.0	2.3	52.5	38,220	.051	

NOTE.—The daily discharges were obtained by interpolation from the measurements.

GILA RIVER AT SAN CARLOS, ARIZ.

The general character of the country through which Gila R flows is a high and rolling plateau, with the river flowing throu in a deep canyon, and with practically no agricultural lands wi its area. The river emerges from its upper canyon about 10 r before it reaches the Arizona line, and thence flows through a va of considerable width, known as Duncan Valley, until just befo receives the waters of San Francisco River. Duncan Valley in w a number of ditches divert water for irrigation purposes was desc at length in the Twenty-first Annual Report.

Gila River is in canyon for about 20 miles below the mouth of San Francisco, or to within 10 miles of Solomonsville. At this p the hills separate, forming a large valley which has been extensi settled and is now one of the finest irrigated portions of the T tory. This valley extends from a point 10 miles above Solomons to 6 miles below the mouth of San Carlos River on the White M tain Indian Reservation. At this latter place the mountains denly close in again and the river enters another canyon. S miles below the Indian agency at San Carlos the canyon boxes width of 100 feet, and at this point is located the San Carlos dam

which was studied by the United States Geological Survey during 1899, in connection with the investigation of the water supply of Gila River. The results of this investigation are published in Water-Supply and Irrigation Paper No. 33, entitled Storage of Water on Gila River, Arizona, by J. B. Lippincott. In connection with this investigation Cyrus C. Babb, on July 11, 1899, established a station on Gila River one-half mile south of the Indian agency at San Carlos and below the mouth of San Carlos Creek. An inclined rod securely fastened to posts driven into the bank was erected here. The bench mark is a 20-penny nail in the base of a mesquite tree 5 inches in diameter, 85 feet west of the gage rod, at an elevation of 12.67 feet above gage datum. Discharge measurements are made from a cable and car a short distance above the gage rod. The channel is straight for some distance above and below the station, and the water is comparatively swift. The right bank is high, but the left is low and liable to overflow. The bed of the stream is sandy and shifting.

Discharge measurements of Gila River at San Carlos, Ariz.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 21	Stephen Janus	1.90	60
January 31	do	1.90	61
February 28	do	1.70	27
March 31	do	([a])	9
Do	do	([a])	9
April 30	do	([a])	5
Do	do	([a])	9
August 7	do	2.50	454
August 15	do	3.20	738
August 22	do	2.50	447
August 26	do	3.40	3,118
September 1	do	2.20	375
September 9	do	1.70	70
September 21	do	2.30	431
September 26	do	1.20	62
October 15	do	([a])	6
November 15	do	([a])	12
December 14	do	3.40	2,485
December 21	do	2.90	1,315
December 31	do	2.20	365

[a] No water at gage.

Daily gage height, in feet, of Gila River at San Carlos, Ariz.

Day.	Jan.	Feb.	Mar.	July.	Aug.	Sept.	D
1902.							
1	2.00	1.90	1.70	.....	1.00	2.20	....
2	2.00	1.90	1.70	.....	1.50	2.20	....
3	2.00	1.90	1.70	.....	1.50	2.10	....
4	2.00	1.90	1.70	.....	1.50	2.10	....
5	2.00	1.90	1.70	.....	1.50	2.00	....
6	2.00	1.90	1.60	.....	1.50	2.00	....
7	2.00	1.90	1.60	.....	2.45	1.90	....
8	2.00	1.90	1.60	.....	1.85	1.80	....
9	2.00	1.90	1.60	.....	1.85	1.70	....
10	2.00	1.90	1.50	.....	2.10	1.70	....
11	2.00	1.90	1.50	.....	2.20	1.70	....
12	2.00	1.90	1.50	.....	2.10	1.70	....
13	2.00	1.90	1.50	.....	3.35	1.60	....
14	2.00	1.90	1.45	.....	3.30	1.60	
15	2.00	1.88	1.45	.....	3.10	1.60	
16	2.00	1.85	1.45	.....	2.25	1.60	
17	2.00	1.85	1.40	.....	2.40	1.60	
18	2.00	1.83	1.40	.....	2.40	1.60	
19	2.03	1.80	1.40	.....	2.05	1.60	
20	1.93	1.80	1.40	.....	1.85	1.60	
21	1.90	1.80	.....	.....	1.65	2.15	
22	1.90	1.80	.....	2.85	1.50	1.45	
23	1.90	1.80	.....	1.95	1.50	1.30	
24	1.90	1.75	.....	1.70	3.45	1.30	
25	1.90	1.70	.....	1.40	3.65	1.20	
26	1.90	1.70	.....	1.45	3.60	1.20	
27	1.90	1.70	.....	.....	2.80	1.10	
28	1.90	1.70	.....	.....	2.90	.....	
29	1.90	.....	.....	.....	3.25	.....	
30	1.90	.....	.....	.....	2.60	.....	
31	1.90	.....	.....	.....	2.30	.....	

NOTE. No water at gage Mar. 23 to July 21, July 27 to 31, Oct. 1 to Dec. 14.

Rating table for Gila River at San Carlos, Ariz., for 1902.

JANUARY 1 to JULY 31.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
1.4	8	2.0	115	2.6	780	3.2	2,010
1.5	12	2.1	190	2.7	955	3.3	2,245
1.6	18	2.2	285	2.8	1,130	3.4	2,480
1.7	26	2.3	395	2.9	1,320	3.5	2,715
1.8	40	2.4	515	3.0	1,540	.....	.....
1.9	70	2.5	640	3.1	1,775	.....	.....

Rating table for Gila River at San Carlos, Ariz., for 1902—Continued.

AUGUST 1 TO DECEMBER 31.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	3	1.7	75	2.4	520	3.1	1,775
1.1	6	1.8	108	2.5	640	3.2	2,010
1.2	11	1.9	150	2.6	780	3.3	2,245
1.3	17	2.0	200	2.7	955	3.4	2,480
1.4	25	2.1	260	2.8	1,130	3.5	2,715
1.5	35	2.2	334	2.9	1,320	3.6	2,950
1.6	50	2.3	420	3.0	1,540	.....	.....

Estimated monthly discharge of Gila River at San Carlos, Ariz.

[Drainage area, 13,455 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	152	70	99.51	6,118.6	0.0074	0.0085
February	70	26	55.43	3,078.4	.0041	.0043
March 1-20	.....	.....	[a] 15.60	625.5	.0011	.00082
April	.....	.....	([a])	.....	.....	.....
May	.....	.....	([a])	.....	.....	.....
June	.....	.....	([a])	.....	.....	.....
July 22-26	.....	.....	[a]118.50	1,308.5	.0089	.0017
August	3,067	3	792.00	48,698.0	.0588	.0670
September 1-27	.....	.....	[a]108.70	5,821.3	.0080	.0080
October	.....	.....	([a])	.....	.....	.....
November	.....	.....	([a])	.....	.....	.....
December 14-31	.....	.....	[a]961.00	34,286.1	.0714	.0480

[a] For these portions of the year there was no water at the gage.

ANIMAS RIVER AT DURANGO, COLO.

The station was first established June 20, 1895, and has been maintained during the greater part of each year since.

The original gage was located at the old wagon bridge one-quarter of a mile west of the railroad station at Durango, and about 200 feet above the Rio Grande Southern Railroad bridge. It was spiked to the west side of the south end of the middle pier of the wagon bridge. The head of a bolt at the east abutment of the railroad bridge is 17.24 feet above gage datum. During the early part of 1899 the old wagon

bridge was removed and a new one erected a short distance bel April 1, 1899, on the central pier of this bridge a new rod, which vertical piece of timber graduated to feet and tenths, was faster The bench marks are three horizontal strips, opposite the 10-, and 16.7-foot marks of the rod, respectively. Owing to this cha in location and height of the rod there is no apparent relation betw the rating tables before 1899 and the rating table for 1899 and af On June 25, 1900, the gage was referred to a new bench mark—a p chiseled on the lower side of the left-hand abutment of the bri 16.84 feet above the zero of the rod. Lightner Creek enters the r from the right about 100 feet below the bridge. The channel at station is straight, the bed is of gravel and bowlders, and the ba are sufficiently high that there is little danger of overflow. observer is C. G. Graden, of Durango.

The following discharge measurements were made during 190 A. L. Fellows:

March 20: Gage height 6.15 feet; discharge, 148 second-feet.
July 12: Gage height 6.72 feet; discharge, 302 second-feet.

Daily gage height, in feet, of Animas River at Durango, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	N
1902.								
1	6.10	8.50	9.10	6.80	6.40	6.80	6.90	
2	6.10	9.00	8.80	6.80	6.40	6.80	7.00	...
3	6.10	9.30	8.90	6.80	6.40	6.70	6.90	...
4	6.20	8.90	9.20	6.80	6.30	6.70	7.00	...
5	6.40	8.70	8.90	6.80	6.30	6.60	6.60	...
6	6.50	9.20	8.80	6.80	6.20	6.50	6.50	...
7	6.60	9.50	8.60	6.80	6.20	6.50	6.40	...
8	6.60	9.20	8.90	6.80	6.20	6.60	6.50	...
9	6.70	9.00	8.80	6.80	6.20	6.50	6.50	...
10	6.90	9.00	8.60	6.80	6.20	6.50	6.70	...
11	6.90	9.50	8.50	6.70	6.20	6.50	6.50	...
12	7.00	9.00	8.50	6.70	6.20	6.60	6.50	...
13	6.90	8.70	8.40	6.70	6.30	6.60	6.50	...
14	6.90	8.60	8.40	6.60	6.40	6.50	6.40	...
15	6.80	8.70	8.00	6.60	6.40	6.50	6.40	...
16	6.80	9.00	7.90	6.60	6.30	6.50	6.50	...
17	7.10	9.00	7.90	6.60	6.30	6.40	6.50	...
18	7.00	8.90	7.80	6.50	6.30	6.30	6.50	...
19	7.20	8.20	7.70	6.50	6.30	6.40	6.50	...
20	7.50	7.90	7.50	6.50	6.30	6.40	6.50	...
21	7.50	7.60	7.30	6.50	6.30	7.00	6.50	...
22	7.40	7.50	7.30	6.50	6.30	6.90	6.50	...
23	7.60	7.50	7.20	6.50	6.40	6.70	6.50	...
24	7.00	7.90	7.20	6.40	6.90	7.00	6.50	...
25	7.00	8.00	7.10	6.40	7.50	7.00	6.50	...
26	6.90	8.10	7.10	6.40	7.50	7.00	6.50	...
27	7.10	8.90	7.00	6.40	7.40	7.00	6.50	...
28	7.30	8.30	7.00	6.40	7.20	6.80	6.50	...
29	7.70	8.50	6.90	6.40	7.10	6.90	6.50	...
30	8.30	8.70	6.90	6.40	7.00	6.90	6.50	...
31	.....	8.40	.....	6.40	6.80	.....	6.50	...

Rating table for Animas River at Durango, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
5.6	50	6.4	206	7.2	540	8.0	1,076
5.7	63	6.5	232	7.3	597	8.2	1,244
5.8	80	6.6	263	7.4	655	8.4	1,427
5.9	100	6.7	300	7.5	717	8.6	1,622
6.0	120	6.8	342	7.6	782	8.8	1,829
6.1	140	6.9	387	7.7	850	9.0	2,050
6.2	160	7.0	435	7.8	922	9.2	2,300
6.3	182	7.1	486	7.9	997	9.4	2,590

Estimated monthly discharge of Animas River at Durango, Colo.

[Drainage area, 812 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	1,334	146	445	26,479	0.549	0.61
May	2,750	717	1,699	104,467	2.092	2.41
June	2,300	387	1,179	70,155	1.452	1.62
July	342	206	271	16,663	.334	.38
August	717	160	273	16,786	.336	.39
September	435	182	299	17,792	.368	.41
October	435	206	256	15,741	.315	.36

FLORIDA RIVER NEAR DURANGO, COLO.

During 1899 work was being done on a large storage project near the head of the river, and on this account a gaging station was established by A. L. Fellows May 19, 1899. It is located at a wagon bridge at Stewart's ranch, which is about 6½ miles east of Durango and is reached by driving. The gage rod consists of a vertical 4-inch strip 7½ feet long, graduated to feet and tenths and spiked to the east abutment of the bridge. The bench mark was established April 15, 1901, and consists of a spike in an 8-inch cottonwood stump, 50 feet south from and 5.86 feet above the zero of the rod. Gagings are made at the wagon bridge, except at low water, when they may be made by wading. Information derived at this point is of importance, as it is desired that the excess water of this stream shall be made available by means of storage reservoirs in the upper part of this drainage basin. Much valuable land can be irrigated if this water is properly conserved. The station was discontinued during 1900. The observer is Mrs. Annie Stewart, who lives near by.

The following discharge measurement was made in 1902 by A. L. Fellows:

July 11: Gage height, 0.80 foot; discharge, 11 second-feet.

Daily gage height, in feet, of Florida River near Durango, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
1	0.80	2.40	1.65	0.90	0.70	0.85	1.00
2	.80	2.50	1.50	.95	.65	.80	1.00
3	.85	2.45	1.45	.95	.60	.80	1.00
4	.90	2.55	1.35	.95	.60	.80	1.00
5	.90	2.10	1.20	.90	.60	.80	1.00
6	1.00	2.10	1.10	.90	.60	.80	1.00
7	1.10	2.20	1.00	.90	.60	.75	1.00
8	1.10	2.05	1.05	.85	.60	.70	.95
9	1.15	1.90	.95	.75	.60	.70	.90
10	1.15	1.80	.85	.70	.60	.70	.90
11	1.30	1.95	.75	.75	.75	.70	.90
12	1.40	1.95	.85	.70	.90	.70	.90
13	1.35	1.90	.75	.70	.90	.65	.90
14	1.35	1.80	.70	.70	.90	.50	.90
15	1.15	1.75	.70	.70	.85	.50	.90
16	1.30	1.80	.70	.70	.80	.60	.90
17	1.50	1.70	.80	.70	.80	.50	.90
18	1.65	1.50	.85	.70	.75	.55	.90
19	1.95	1.35	.80	.70	.70	.55	.90
20	1.90	1.20	.75	.70	.70	.50	.90
21	1.85	1.15	.75	.70	.70	1.20	.70
22	1.45	1.15	.75	.70	.70	1.85	.70
23	1.25	1.10	.70	.70	.85	1.70	.70
24	1.25	1.30	.80	.75	1.90	1.75	.70
25	1.35	1.55	.75	.70	1.75	1.40	.70
26	1.55	1.50	.85	.80	1.45	1.25	.60
27	1.50	1.95	.85	.75	1.35	1.10	.60
28	1.90	1.90	.80	.75	1.20	1.00	[illegible]
29	2.05	1.85	.85	.70	1.15	1.00	[illegible]
30	2.45	1.70	.80	.70	1.00	1.00	[illegible]
31	.....	1.75	.....	.70	1.00	.....	[illegible]

Rating table for Florida River near Durango, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.5	5	1.4	45	2.3	248	3.2	482
.6	7	1.5	56	2.4	274	3.3	508
.7	9	1.6	74	2.5	300	3.4	534
.8	11	1.7	98	2.6	326	3.5	560
.9	15	1.8	122	2.7	352	3.6	586
1.0	19	1.9	146	2.8	378	3.7	612
1.1	24	2.0	170	2.9	404		
1.2	30	2.1	196	3.0	430		
1.3	37	2.2	222	3.1	456		

Estimated monthly discharge of Florida River near Durango, Colo.

[Drainage area, 136 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	287	11	63	3,749	0.46	0.51
May	313	24	134	8,239	.99	1.14
June	86	9	19	1,131	.14	.16
July	17	9	11	676	.08	.09
August	146	7	21	1,291	.15	.17
September	134	5	23	1,369	.17	.19
October	19	7	13	799	.10	.12

LOS PINOS RIVER AT IGNACIO, COLO.

The station was established April 22, 1899, at the request of the Commissioner of Indian Affairs, for the purpose of ascertaining the quantity of water available for irrigation along the stream. It is located at the wagon bridge at Ignacio, the subagency of the Southern Ute Indian Reservation, 2 miles north of the Denver and Rio Grande Railroad station. The rod is a vertical 2 by 4 inch timber, 10 feet long, spiked to the bridge, the marks being strips of brass securely nailed to the post. Bench mark No. 1 is the 8-foot mark on the gage rod, which is level with the top of the lower end of a 6 by 8 inch timber protruding downstream from the pier on the right-hand side. Bench mark No. 2, placed April 7, is an iron bench-mark post set 30 feet northwest from the northwest corner of the bridge, its top being 7.64 feet above the zero of the gage. The observer is John Wesch, the clerk at the agency. The banks are low, but not subject to overflow; the bed of the stream is of gravel, but not liable to radical change.

The following discharge measurements were made during 1902 by A. L. Fellows:

March 27: Gage height, 2.44 feet; discharge, 57 second-feet.
July 11: Gage height, 2.15 feet; discharge, 39 second-feet.

Daily gage height, in feet, of Los Pinos River at Ignacio, Colo.

Day.	Apr.	May.	June.	Day.	Apr.	May.	June.
1902.				1902.			
1	2.40	3.60	3.30	17	3.00	3.35	
2	2.40	3.70	3.30	18	3.05	3.35	
3	2.40	3.75	3.25	19	3.30	3.35	
4	2.40	3.60	3.15	20	3.40	3.35	
5	2.40	3.50	3.05	21	3.30	3.25	
6	2.45	3.60	3.05	22	3.30	3.25	
7	2.70	3.65	3.05	23	3.35	3.25	
8	2.80	3.65	3.05	24	3.20	3.35	
9	2.85	3.45	3.00	25	3.10	3.35	
10	3.00	3.45	2.95	26	3.00	3.25	
11	3.10	3.50	2.90	27	3.00	3.25	
12	3.00	3.50	2.85	28	3.15	3.35	
13	2.95	3.50	2.85	29	3.30	3.35	
14	2.95	3.45	2.80	30	3.50	3.40	
15	2.90	3.45	(a)	31		3.40	
16	2.95	3.35					

a No observer available.

Rating table for Los Pinos River at Ignacio, Colo.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.0	25	2.9	259	3.8	795	4.7	1,352
2.1	32	3.0	315	3.9	856	4.8	1,414
2.2	43	3.1	375	4.0	918	4.9	1,476
2.3	56	3.2	435	4.1	980	5.0	1,538
2.4	73	3.3	495	4.2	1,042	5.1	1,600
2.5	95	3.4	555	4.3	1,104	5.2	1,662
2.6	125	3.5	615	4.4	1,166		
2.7	163	3.6	675	4.5	1,228		
2.8	208	3.7	735	4.6	1,290		

Estimated monthly discharge of Los Pinos River at Ignacio, Colo.

[Drainage area, 450 square miles.]

Month.	Discharge in second-feet.			Total in acre feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	615	73	312	18,565	0.69	0.77
May	765	465	577	35,478	1.28	1.48
June 1–14			341	9,469	.76	.40

DOLORES RIVER AT DOLORES, COLO.

This station was established by F. Cogswell in June, 1895. The gage is located about one-half mile above the railroad station, at the footbridge from which the measurements of discharge are made. The gage is vertical, and is spiked to the crib abutment of the bridge on the left bank. The bench mark consists of a nail driven into the base of a cottonwood tree 18 feet southwest from the gage. This is 1.57 feet above the 14-foot mark. The locality is especially good for accurate measurement, as the bed of the stream is apparently permanent and the banks are not liable to overflow at moderate stages.

The observer is Mary D. Smith.

The following discharge measurement was made in 1902 by A. L. Fellows:

July 14: Gage height, 2.65 feet; discharge, 47 second-feet.

Daily gage height, in feet, of Dolores River at Dolores, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
1	2.70	4.60	3.95	2.80	2.50	2.80	2.60
2	2.70	4.55	3.85	2.80	2.50	2.80	2.60
3	2.80	4.45	3.75	2.85	2.50	2.75	2.60
4	2.90	4.25	3.75	2.90	2.50	2.70	2.60
5	3.00	4.05	3.70	2.90	2.50	2.65	2.60
6	3.00	4.05	3.70	2.90	2.50	2.60	2.55
7	3.10	4.15	3.55	2.90	2.50	2.60	2.50
8	3.20	4.15	3.55	2.85	2.45	2.60	2.50
9	3.25	4.15	3.50	2.80	2.40	2.60	2.60
10	3.35	4.05	3.45	2.80	2.45	2.55	2.60
11	3.45	4.05	3.40	2.75	2.55	2.50	2.60
12	3.50	4.10	3.40	2.70	2.75	2.50	2.60
13	3.50	3.70	3.40	2.70	2.80	2.50	2.60
14	3.50	4.10	3.40	2.60	2.80	2.50	2.60
15	3.50	4.15	3.25	2.60	2.80	2.50	2.60
16	3.50	4.15	3.20	2.60	2.80	2.50	2.60
17	3.50	4.15	3.20	2.60	2.70	2.60	2.60
18	3.65	3.95	3.15	2.70	2.70	2.60	2.60
19	3.80	3.80	3.00	2.70	2.70	2.60	2.60
20	4.00	3.65	3.00	2.60	2.65	2.65	2.60
21	3.95	3.60	3.00	2.60	2.60	3.00	2.55
22	3.80	3.60	2.95	2.60	2.65	3.15	2.50
23	3.90	3.50	2.90	2.60	2.85	2.95	2.50
24	3.95	3.50	2.90	2.55	3.25	2.90	2.50
25	3.80	3.60	2.90	2.55	3.30	2.90	2.50
26	3.60	3.70	2.90	2.60	3.30	2.85	2.50
27	3.65	4.00	2.90	2.65	3.15	2.80	2.55
28	3.75	4.05	2.90	2.65	3.00	2.75	2.60
29	4.10	4.20	2.90	2.60	3.00	2.75	2.60
30	4.40	4.05	2.90	2.60	3.00	2.70	2.60
31	.....	4.10	.....	2.50	3.00	.....	2.60

Rating table for Dolores River at Dolores, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discha
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second*
2.4	20	3.0	150	3.6	556	4.2	1,0
2.5	28	3.1	205	3.7	628	4.3	1,0
2.6	37	3.2	271	3.8	700	4.4	1,1
2.7	51	3.3	341	3.9	773	4.5	1,2
2.8	73	3.4	412	4.0	849	4.6	1,3
2.9	106	3.5	484	4.1	925		

Estimated monthly discharge of Dolores River at Dolores, Colo.

[Drainage area, 524 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	De in
1902.						
April	1,157	51	497	29,574	0.948	
May	1,323	484	857	52,695	1.635	
June	811	106	342	20,350	.653	
July	106	28	56	3,443	.107	
August	341	20	92	5,657	.176	
September	237	28	62	3,689	.118	
October	37	28	34	2,091	.065	

GUNNISON RIVER AT WHITEWATER, COLO.

This station was established by J. E. Field April 10, 1902, at a wagon bridge constructed by the State of Colorado at a point a half a mile above the railroad station at Whitewater, on the De and Rio Grande Railroad. During 1895, 1897, and 1901 incom series of gage heights were obtained at this point, but the st was not regularly established until 1902. It was intended that station should take the place of the one formerly maintained o Gunnison at Grand Junction. The latter station was abandon account of inaccuracies that could not be overcome. They mainly due to the fact that high stages of water in Grand I affected the gage rod in the Gunnison, and that the stream bed was tially filled with great bowlders, making accurate gagings impos

Discharge measurements of Gunnison River at Whitewater, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 10	J. E. Field	4.60	[a] 2,176
May 26	M. C. Hinderlider	6.10	3,322
July 31	do	3.20	384
August 30	do	4.60	1,230
September 20	G. H. Matthes	3.20	302
November 1	J. E. Field	3.80	622

[a] Sometime during the spring, between April 10 and May 26, a dam was placed across the river about 1¼ miles below the gaging station, which affected the gage heights at the bridge where gage is located. In the latter part of the summer part of the dam went out, thereby again changing the readings of gage rod. No definite conclusions could be arrived at as to the extent to which the river surface at gage rod was affected by the construction and later breaking of the dam. The gaging of April 10 was not used in constructing the rating table.

Daily gage height, in feet, of Gunnison River at Whitewater, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
1	3.00	6.35	7.60	3.70	3.20	4.45	3.60
2	3.00	7.35	7.50	3.75	3.20	4.35	3.50
3	3.00	7.90	7.15	3.80	3.45	4.25	3.45
4	3.10	8.30	7.00	3.75	3.50	4.00	3.40
5	3.25	8.15	7.00	3.70	3.50	3.85	3.30
6	3.35	8.00	6.95	3.85	3.50	3.80	3.30
7	3.40	8.25	6.85	4.40	3.45	3.70	3.45
8	3.55	8.40	6.80	4.15	3.40	3.70	3.55
9	3.70	8.25	6.90	3.90	3.40	3.60	3.85
10	3.75	8.30	6.75	3.80	3.55	3.60	4.00
11	3.95	8.55	6.60	3.70	3.70	3.60	4.20
12	4.05	8.75	6.45	3.60	3.70	3.50	3.90
13	4.15	8.65	6.30	3.50	3.80	3.50	3.65
14	4.35	8.45	6.40	3.40	3.80	3.40	3.60
15	4.45	8.25	6.15	3.35	3.95	3.50	3.50
16	4.60	8.05	5.85	3.30	4.30	3.60	3.50
17	4.85	8.05	5.65	3.60	3.95	3.70	3.50
18	5.10	7.85	5.55	3.90	3.70	3.75	3.50
19	5.40	7.50	5.35	3.65	3.60	3.60	3.50
20	5.60	6.90	5.05	3.50	3.65	3.65	3.50
21	5.70	6.40	5.00	3.35	3.80	3.80	3.40
22	5.85	6.15	4.90	3.70	3.90	3.90	3.40
23	5.55	5.85	4.60	3.85	3.80	3.90	3.40
24	5.10	5.70	4.45	3.80	3.70	4.60	3.40
25	4.85	5.65	4.35	3.70	3.60	4.90	3.40
26	4.80	6.15	4.15	3.60	3.75	4.40	3.40
27	4.80	6.90	4.00	3.60	3.95	3.70	3.40
28	4.80	8.05	4.00	3.60	4.00	3.70	3.55
29	5.15	7.85	3.95	3.70	4.25	3.60	3.60
30	5.90	7.70	3.80	3.70	4.60	3.60	3.75
31	.....	7.35	.....	3.35	4.50	.....	3.80

Rating table for Gunnison River at Whitewater, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discha
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-*
3.0	260	4.6	1,169	6.2	3,528	7.8	8,2
3.2	341	4.8	1,359	6.4	3,982	8.0	9,0
3.4	427	5.0	1,571	6.6	4,477	8.2	9,8
3.6	521	5.2	1,815	6.8	5,012	8.4	10,6
3.8	623	5.4	2,091	7.0	5,587	8.6	11,5
4.0	734	5.6	2,399	7.2	6,195	8.8	12,5
4.2	860	5.8	2,739	7.4	6,838		
4.4	1,004	6.0	3,116.	7.6	7,515		

Estimated monthly discharge of Gunnison River at Whitewater, Colo.

[Drainage area, 7,868 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	D i
1902.						
April	2,922	260	1,219	72,535	0.16	
May	12,271	2,481	7,772	477,885	.99	
June	7,515	623	3,284	195,411	.42	
July	1,004	383	570	35,048	.07	
August	1,169	341	610	37,507	.08	
September	1,461	427	667	39,689	.08	
October	860	383	504	30,990	.06	

GUNNISON RIVER AT IOLA, COLO.

The Iola station was established in March, 1900, for the purpo determining the amount of water available for the irrigation pr of Uncompahgre Valley. The rod is at a wagon bridge which cr the river about a quarter of a mile above the Denver and Rio Gr Railroad station at Iola. It consists of a piece of 2-inch by 4 timber fastened to the downstream side of the second pier of bridge from the south end, the zero of the rod being 7.43 feet l the bench mark—a spike in the base of an old post 40 feet sou the southern end of the bridge, on the west side of the road. chief value of the station is with reference to determining the am of water available for the proposed canal to the Uncompahgre Va although, owing to the fact that a number of streams enter the *nison below the station*, the results obtained do not show the

amount available. The channel at this place is wide, and the bed being of gravel and bowlders is not particularly susceptible to change. The banks, though not high, are not subject to overflow. The observer, A. Pomel, postmaster at Iola, telegraphs the gage height daily to the local forecast official of the United States Weather Bureau at Denver, who has it printed in the morning papers.

During 1902 the following discharge measurements were made by M. C. Hinderlider and A. L. Fellows:

May 30: Gage height, 3.60 feet; discharge, 1,925 second-feet.
July 19: Gage height, 1.90 feet; discharge, 271 second-feet.
September 1: Gage height, 2.10 feet; discharge, 400 second-feet.

Daily gage height, in feet, of Gunnison River at Iola, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	2.20	3.00	3.70	2.00	1.80	2.00	1.80	2.00
2	2.30	3.20	3.60	2.00	1.80	2.00	1.80	2.00
3	2.30	3.40	3.20	2.00	1.80	2.00	1.90	2.00
4	2.50	3.40	3.20	2.00	1.80	1.90	2.00	2.00
5	2.60	3.60	3.30	2.00	1.80	1.90	2.00	2.00
6	2.70	3.70	3.20	2.30	1.80	1.90	2.00	2.00
7	2.70	3.60	3.20	2.10	1.80	1.90	2.00	2.00
8	2.60	3.80	3.20	2.00	1.80	1.90	1.90	2.00
9	2.60	3.80	3.10	2.00	1.80	1.80	2.00	2.00
10	2.60	4.00	3.00	1.90	1.80	1.80	2.00	2.00
11	2.50	4.00	3.00	1.90	1.80	1.80	2.00	2.10
12	2.50	4.00	3.00	2.00	1.80	1.80	2.00	2.10
13	2.40	3.90	3.00	1.80	1.90	1.80	2.00	2.20
14	2.30	3.90	3.00	1.80	1.90	1.80	2.00	2.20
15	2.30	3.80	2.90	1.80	1.90	1.80	1.90	2.20
16	2.40	3.80	2.80	1.80	1.90	1.80	1.90	2.20
17	2.50	3.80	2.70	1.80	1.90	1.80	1.90	2.20
18	2.60	3.60	2.60	1.80	1.90	1.80	1.90	2.10
19	2.70	3.20	2.60	1.80	1.90	1.80	2.00	2.10
20	2.70	3.00	2.50	1.80	1.80	1.80	2.00	2.20
21	2.70	2.90	2.50	1.80	1.80	1.90	2.00	2.20
22	2.60	2.80	2.40	1.80	1.80	1.90	2.00	2.20
23	2.60	2.80	2.30	1.80	1.90	1.80	2.00	2.10
24	2.50	2.80	2.20	1.80	1.90	1.80	2.00	2.10
25	2.50	3.00	2.20	1.80	2.00	1.80	2.00	2.10
26	2.50	3.20	2.10	1.80	2.10	1.80	2.00	2.20
27	2.60	3.80	2.00	1.80	2.10	1.80	2.00	2.20
28	2.80	3.60	2.00	1.80	2.10	1.80	2.00	2.20
29	2.11	3.60	2.00	1.80	2.10	1.80	2.00	2.20
30	3.00	3.60	2.00	1.80	2.10	1.80	2.00	.....
31	.....	3.60	.....	1.80	2.10	.....	2.00	.....

Rating table for Gunnison River at Iola, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.8	221	2.4	640	3.0	1,205	3.6	1,925
1.9	271	2.5	728	3.1	1,308	3.7	2,090
2.0	330	2.6	818	3.2	1,413	3.8	2,264
2.1	398	2.7	910	3.3	1,522	3.9	2,446
2.2	474	2.8	1,005	3.4	1,638	4.0	2,636
2.3	555	2.9	1,104	3.5	1,772		

Estimated monthly discharge of Gunnison River at Iola, Colo.

[Drainage area, 3,[illegible] square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	1,205	403	759	45,164	0.88	0.97
May	2,636	1,005	1,838	113,015	.80	.92
June	2,090	330	997	59,326	.43	.48
July	555	221	269	16,540	.12	.14
August	398	221	273	16,786	.12	.14
September	330	221	244	14,519	.11	.12
October	330	221	312	19,184	.14	.16
November	474	330	408	24,278	.18	.20

GRAND RIVER NEAR PALISADES, COLO.

This station was established April 9, 1902, by John E. Field, at the iron wagon bridge across Grand River where the river enters Grand Valley about 2 miles above Palisades. The channel at this point is deep and rocky, the mountains rising on either side rather abruptly. The station is above all irrigating ditches supplying water to the land of Grand Valley with the exception of one pumping plant, which takes about 20 second-feet of water from the river one-fourth of a mile above the station. The river at this point is deep and at high water very swift. The right bank is high and precipitous; the left bank for a short distance below the bridge is liable to overflow for a short distance out during very high water. The bed of the river is somewhat changeable, but for a river of this size fairly satisfactory results are obtained. The gage consists of a wire cable, to which a window weight is attached, swung from the middle of the bridge. The graduations are painted in feet and tenths on the hub rail on the

bridge. No bench mark has ever been established. The observations have been taken twice daily during the irrigating season since the station was established by S. L. Purdy, pumpman at the Mount Lincoln pumping plant.

Discharge measurements of Grand River near Palisades, Colo.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 9	J. E. Field	12.30	2,564
May 27	M. C. Hinderlider	16.30	9,778
July 30	do	12.20	1,966
August 29	do	12.00	1,662
October 2	G. H. Matthes	12.15	1,415
October 15	do	12.20	1,465
October 26	do	12.20	1,361
November 3	do	12.10	1,346

Daily gage height, in feet, of Grand River near Palisades, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	11.60	14.15	17.75	13.75	12.25	12.00	12.10	(a)
2	11.60	15.00	17.55	13.75	11.98	12.00	12.20	.....
3	11.60	15.75	17.25	13.55	11.95	12.00	12.27	.....
4	11.60	16.30	17.10	13.42	11.92	11.95	12.25	.....
5	11.60	16.65	17.10	13.42	11.92	11.88	12.25	.....
6	11.70	16.90	17.10	13.38	11.90	11.80	12.20	.....
7	11.70	17.05	17.00	13.35	11.82	11.80	12.25	.....
8	12.30	17.30	16.95	13.25	11.80	11.75	12.18	.....
9	12.30	17.50	17.00	13.15	11.80	11.72	12.12	.....
10	12.40	17.75	16.95	12.98	11.75	11.72	12.10	.....
11	12.35	18.30	16.80	12.85	12.08	11.68	12.10	.....
12	12.35	18.45	16.65	12.70	11.80	11.60	12.10	.....
13	12.30	18.20	16.55	12.68	11.75	11.60	12.25	.....
14	12.35	18.30	16.45	12.70	11.75	11.60	12.30	.....
15	12.30	18.45	16.15	12.68	11.85	11.60	12.20	.....
16	12.20	18.55	15.95	12.60	11.98	11.60	12.25	.....
17	12.20	18.60	15.75	12.95	12.00	11.60	12.25	.....
18	12.25	18.25	15.45	12.68	11.48	11.60	12.25	.....
19	12.38	17.85	15.25	12.72	11.85	11.75	12.25	.....
20	12.65	17.10	14.95	13.25	11.78	11.70	12.20	.....
21	12.95	16.55	14.75	12.98	11.72	12.35	12.20	.....
22	13.27	16.00	14.55	12.75	11.70	12.15	12.20	.....
23	13.30	15.55	14.42	12.58	11.70	12.10	12.18	.....
24	12.95	15.30	14.38	12.45	11.65	12.10	12.20	.....
25	12.72	15.25	14.30	12.40	11.78	12.10	12.20	.....
26	12.72	15.75	14.08	12.32	11.85	12.10	12.18	.....
27	12.62	15.65	13.95	12.30	12.00	12.10	12.20	.....
28	12.72	17.45	13.80	12.28	11.60	12.10	12.18	.....
29	13.05	17.20	13.70	12.22	12.00	12.10	12.18	.....
30	13.55	17.30	13.65	12.18	12.10	12.10	12.10	.....
31	.....	17.55	.....	12.12	12.00	.....	12.10	.....

[a] Station closed for winter.

Rating table for Grand River near Palisades, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
11.6	1,102	13.4	3,955	15.2	7,444	17.0	11,542
11.8	1,376	13.6	4,323	15.4	7,867	17.2	12,082
12.0	1,662	13.8	4,698	15.6	8,311	17.4	12,624
12.2	1,960	14.0	5,079	15.8	8,756	17.6	13,171
12.4	2,268	14.2	5,464	16.0	9,204	17.8	13,722
12.6	2,584	14.4	5,853	16.2	9,654	18.0	14,282
12.8	2,911	14.6	6,246	16.4	10,106	18.2	14,876
13.0	3,248	14.8	6,642	16.6	10,562	18.4	15,518
13.2	3,596	15.0	7,041	16.8	11,029	18.6	16,208

Estimated monthly discharge of Grand River near Palisades, Colo.

[Drainage area, 8,546 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	4,230	1,102	2,230	132,694	0.26	0.2
May	16,208	5,367	11,800	725,554	1.38	1.5
June	13,584	4,416	8,873	527,980	1.04	1.1
July	4,604	1,839	3,024	185,939	.35	.4
August	2,036	944	1,479	90,941	.17	.2
September	2,190	1,102	1,489	88,602	.17	.1
October	2,113	1,809	1,951	119,963	.23	.2

GRAND RIVER AT GLENWOOD SPRINGS, COLO.

This station was first located May 12, 1899, at the request of the Denver and Rio Grande Railroad Company, at the railroad bridge a quarter of a mile west of the depot and just above the mouth of Roaring Fork. A wire gage was used. At the beginning of 1900, however, a new gage rod was located near the electric-light works of the Colorado Hotel. Measurements are made from the wagon bridge crossing the river between the town and the hotel. The channel is good, being composed of gravel and rock, and does not change much the banks are high and not subject to overflow.

During 1902 the following discharge measurements were made by J. E. Field and M. C. Hinderlider.

April 11: Gage height, 3.87 feet; discharge, 1,328 second-feet.
July 28: Gage height, 3.90 feet; discharge, 1,414 second-feet.
August 28: Gage height, 3.60 feet; discharge, 1,079 second-feet.
November 3: Gage height, 3.30 feet; discharge, 842 second-feet.
December 13: Gage height, 3.30 feet; discharge, 775 second-feet.

Daily gage height, in feet, of Grand River at Glenwood Springs, Colo.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.[a]	Dec.
1902.									
1	3.10	3.10	3.25	3.15	5.40	7.75	5.00	.....	.....
2	3.15	3.00	3.20	3.20	5.95	7.65	4.80	.....	.....
3	3.15	2.90	3.20	3.25	6.45	7.40	4.75	.....	2.90
4	3.35	3.00	3.15	3.30	6.75	7.20	4.70	.....	2.90
5	3.25	3.05	3.15	3.40	6.90	7.35	4.60	.....	3.10
6	3.20	3.20	3.25	3.50	6.90	7.30	4.60	.....	3.20
7	3.20	3.20	3.20	3.60	6.70	7.80	4.60	.....	3.20
8	3.20	3.20	3.15	3.70	7.20	7.30	4.45	.....	3.10
9	3.20	3.20	3.25	3.90	7.40	7.40	4.30	.....	3.25
10	3.15	3.20	3.25	3.90	7.50	7.35	4.20	.....	3.25
11	3.10	3.20	3.25	3.85	7.80	7.30	4.20	.....	3.30
12	3.00	3.25	3.25	3.85	7.95	7.15	4.15	.....	3.30
13	3.05	3.30	3.25	3.90	7.80	7.00	4.10	.....	3.30
14	3.10	3.15	3.25	3.90	7.90	6.90	4.10	.....	3.30
15	3.00	3.15	3.15	3.80	8.10	6.65	4.00	.....	3.05
16	3.05	3.30	3.10	3.70	8.20	6.50	4.00	.....	2.85
17	3.20	3.25	3.20	3.70	8.15	6.30	4.00	.....	2.80
18	3.15	3.25	3.25	3.80	7.95	6.10	4.15	.....	2.58
19	3.10	3.30	3.30	3.95	7.75	5.95	4.55	.....	3.05
20	3.15	3.20	3.30	4.15	7.25	5.80	4.60	.....	3.05
21	3.10	3.20	3.35	4.30	6.80	5.60	4.35	.....	3.05
22	2.90	3.30	3.35	4.65	6.35	5.50	4.20	.....	3.05
23	3.20	3.30	3.30	4.45	6.10	5.35	4.10	.....	2.95
24	3.05	3.20	3.30	4.20	5.95	5.35	4.00	.....	3.05
25	3.15	3.30	3.30	4.10	5.95	5.20	3.90	.....	3.25
26	3.05	3.30	3.30	4.10	6.30	5.10	3.90	.....	3.30
27	3.00	3.30	3.30	4.10	7.10	5.10	3.80	.....	3.23
28	2.95	3.20	3.30	4.25	7.50	5.00	.....	.....	3.28
29	3.10	.....	3.25	4.55	7.35	4.90	.....	.....	(b)
30	3.10	.....	3.15	4.90	7.45	4.95	.....	.....	(b)
31	3.10	.....	3.15	.....	7.65	.....	.....	.....	(b)

[a] Automatic register placed on July 28. Never worked satisfactorily. Cause of break in record.

[b] Wire on gage broken.

Rating table for Grand River at Glenwood Springs, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.0	650	4.4	1,969	5.8	5,109	7.2	9,996
3.2	775	4.6	2,242	6.0	5,769	7.4	10,763
3.4	920	4.8	2,584	6.2	6,430	7.6	11,546
3.6	1,079	5.0	2,968	6.4	7,104	7.8	12,340
3.8	1,266	5.2	3,392	6.6	7,800	8.0	13,154
4.0	1,485	5.4	3,881	6.8	8,522	8.2	13,980
4.2	1,722	5.6	4,466	7.0	9,254		

Estimated monthly discharge of Grand River at Glenwood Springs, Colo.

[Drainage area, 5,838 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	882	600	721	44,332	0.123	0.14
February	845	600	775	43,041	.133	.14
March	882	710	802	49,313	.138	.16
April	2,772	742	1,419	84,436	.244	.27
May	13,980	3,881	9,825	604,120	1.683	1.94
June	12,140	2,772	7,316	435,332	1.253	1.39
July 1 to 27	.....	.....	1,864	99,824	.321	.37
December 3 to 28	.....	.....	723	37,285	.124	.12

WHITE RIVER AT MEEKER, COLO.

This station was established by A. L. Fellows, May 24, 1901, about one-half of a mile above the town of Meeker, at a point where a wagon bridge crosses the stream on the ranch of L. F. Van Cleave. The gage rod consists of a vertical 2 by 4 inch timber nailed to the left abutment of the bridge on the downstream side. The bridge is marked every 5 feet. The initial point for soundings is at the rod at the left or south end of the bridge. The banks are so high that they are not liable to overflow; the channel is of rock and gravel, and seems permanent in its nature. Measurements are made from the lower side of the wagon bridge. The observer is L. F. Van Cleave, who reads the rod twice each day.

The following discharge measurements were made during 1902 by A. J. McCune and J. E. Field:

July 6: Gage height, 4.00 feet; discharge, 472 second-feet.
Oct. 17: Gage height, 2.55 feet; discharge, 342 second-feet.

Daily gage height, in feet, of White River at Meeker, Colo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.							
1	3.55	4.70	5.40	3.85	3.30	3.60	3.60
2	3.55	4.85	5.35	3.95	3.35	3.55	3.60
3	3.50	5.20	5.15	3.90	3.35	3.55	3.50
4	3.60	5.25	5.20	3.80	3.35	3.50	3.50
5	3.60	5.25	5.25	3.95	3.35	3.50	3.50
6	3.60	5.30	5.10	4.05	3.35	3.50	3.50
7	3.70	5.50	5.10	3.95	3.35	3.50	3.50
8	3.80	5.65	5.00	3.90	3.35	3.50	3.50
9	3.75	5.75	4.95	3.85	3.30	3.50	3.50
10	3.70	5.70	4.90	3.80	3.30	3.40	3.50
11	3.65	5.80	4.80	3.80	3.30	3.40	3.50
12	3.70	5.70	4.95	3.75	3.40	3.50	3.70
13	3.70	5.65	4.65	3.75	3.40	3.45	3.65
14	3.60	5.70	4.65	3.70	3.45	3.45	3.55
15	3.55	5.70	4.55	3.65	3.40	3.50	3.55
16	3.60	5.70	4.45	3.60	3.40	3.50	3.50
17	3.70	5.70	4.30	3.70	3.40	3.45	3.50
18	3.75	5.60	4.25	3.80	3.40	3.45	3.50
19	3.95	5.25	4.20	3.70	3.40	3.50	3.50
20	4.05	5.10	4.10	3.65	3.40	3.50	3.50
21	4.15	4.85	4.10	3.60	3.40	3.70	3.50
22	4.00	4.75	3.95	3.60	3.40	3.70	3.50
23	3.95	4.70	3.95	3.55	3.40	3.60	3.55
24	3.85	4.60	3.90	3.50	3.45	3.60	3.50
25	3.80	4.60	3.80	3.50	3.50	3.60	3.50
26	3.80	4.90	3.80	3.50	3.50	3.60	3.50
27	3.80	5.15	3.75	3.50	3.50	3.60	3.50
28	4.00	5.30	3.75	3.50	3.50	3.60	3.50
29	4.20	5.35	3.90	3.40	3.50	3.60	3.50
30	4.45	5.25	3.90	3.40	3.50	3.60	3.50
31	.....	5.60	.....	3.30	3.50	.....	3.50

Rating table for White River at Meeker, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.7	300	3.4	372	4.2	523	5.6	2,614
2.8	308	3.5	384	4.4	594	5.8	3,284
2.9	317	3.6	397	4.6	696	6.0	4,034
3.0	327	3.7	412	4.8	845	6.2	4,834
3.1	337	3.8	429	5.0	1,100	6.4	5,634
3.2	348	3.9	448	5.2	1,514		
3.3	360	4.0	469	5.4	2,024		

Estimated monthly discharge of White River at Meeker, Colo.

[Drainage area, 634 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dept inch
1902.						
April	616	384	433	25,765	0.68	(
May	3,284	696	1,927	118,487	3.04	:
June	2,024	420	843	50,162	1.33	1
July	481	360	414	25,456	.65	
August	384	360	372	22,873	.59	
September	412	372	389	23,147	.61	
October	412	384	387	23,796	.61	

UINTA RIVER AT OURAY SCHOOL, NEAR LELAND, UTAH.

This station was established November 8, 1899, and is located the highway bridge over the river near the Ouray School. It is ab 5 miles below the station at Fort Duchesne. Dry Gulch Creek ent from the west, and except during flood stages carries practically o the waste water of Canal No. 1 and the Bench ditch, thereby accou ing for the increase in flow between this point and the Fort Duche station. The rod is nailed to the east end of the south crib of wagon bridge. Bench mark No. 1 is the head of a nail in the extr northeast corner of the bridge floor, and is at an elevation of 4,74 feet above sea; bench mark No. 2 is a nail in the flagstaff of school, with an elevation of 4,760 feet. The elevation of the zer the rod is 4,737.36 feet. During low water measurements are ma by wading, at a section 200 feet below the bridge, and at high sta they are made from the bridge itself. The section is a good although the center pier of the bridge will interfere somewhat v the accuracy of the results when measurements are taken there.

arge measurements of Uinta River at Ouray School, near Leland, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
27	C. T. Prall	0.56	122
	do	.36	89
)	do	.31	81
7	do	.24	72
4	do	.39	95
	do	.35	90
	do	.69	144
	do	2.65	919
	do	1.60	397
	do	3.50	2,224
	do	2.85	1,143
	do	2.32	732
	do	1.70	426
	do	1.20	285
	do	1.22	278
	do	.67	150
	H. S. Reed	.24	75
	do	.03	47
7	do	-.16	35
14	do	.03	51
21	do	-.12	36
28	do	.05	48
ber 4	do	.06	52
ber 11	do	-.08	35
ber 18	do	.07	50
ber 25	do	.33	81
r 2	do	.30	78
r 9	do	.33	84
r 23	do	.33	81
r 30	do	.40	87
ber 7	do	.33	83
ber 13	do	.60	119
ber 20	do	.54	109
ber 26	do	.15	60
ber 4	do	.33	57
ber 10	do	.63	104
ber 19	do	.65	89

Daily gage height, in feet, of Uinta River at Ouray School, near Leland, Ut for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	(a)	(a)	(a)	0.46	0.31	3.45	1.28	0.01	0.19	0.30	0.40	0.
2	.....	.....	.....	.36	.32	3.65	1.39	− .04	.15	.30	.50	.
3	.....	.....	.....	.38	.31	2.60	1.20	− .08	.11	.30	.40	.
4	.....	.....	.....	.38	.35	2.50	1.18	− .09	.08	.30	.38	.
5	.....	.....	.....	.36	.32	2.55	1.10	− .06	.01	.31	.40	.
6	.....	.....	.....	.38	.45	2.60	1.10	− .12	− .01	.33	.35	.
7	.....	.....	.....	.35	.51	2.60	1.00	− .14	− .02	.34	.35	.
8	.....	.....	.....	.40	.70	2.68	.85	− .17	− .03	.35	.37	.
9	.....	.....	.....	.40	.88	2.68	.70	− .19	− .03	.35	.39	.
10	.....	.....	.....	.38	1.33	2.50	.68	− .21	− .04	.34	.40	.
11	.....	.....	.....	.32	1.90	2.54	.60	− .23	− .06	.35	.....	.
12	.....	.....	.....	.35	2.24	2.40	.59	.00	− .08	.35	.72	.
13	.....	.....	.....	.38	2.35	2.20	.55	.05	− .09	.37	.63	.
14	.....	.....	.....	.31	2.50	2.10	.45	.01	− .11	.38	.45	.
15	.....	.....	.....	.31	2.75	2.00	.39	.06	− .11	.38	.50	.
16	.....	.....	.....	.27	2.55	1.85	.38	.07	.00	.38	.38	.
17	.....	.....	.....	.28	2.90	1.74	.40	− .01	.05	.37	.35	.
18	.....	.....	.....	.26	2.53	1.68	.48	− .05	.06	.35	.43	.
19	.....	.....	.....	.29	2.30	1.53	.40	− .12	.07	.35	.32	.
20	.....	.....	.....	.30	1.96	1.48	.36	− .03	.07	.38	.53	.
21	.....	.....	.....	.45	1.80	1.48	.32	− .02	1.80	.38	.51	(
22	.....	.....	.....	.68	1.59	1.40	.28	− .13	.58	.36	.52	...
23	.....	.....	.....	.41	1.48	1.32	.28	− .14	.40	.35	.52	...
24	.....	.....	.....	.45	1.30	1.28	.25	− .15	.36	.33	.50	...
25	.....	.....	.....	.40	1.44	1.24	.20	− .12	.32	.33	.45	...
26	.....	.....	.....	.38	1.85	1.20	.20	− .10	.30	.33	.40	...
27	.....	.....	.....	.38	2.95	1.12	.15	− .11	.30	.35	.40	...
28	.....	.....	.....	.35	3.53	1.18	.12	.01	.30	.33	.42	...
29	.....	.....	.....	.32	3.75	1.50	.11	.18	.31	.38	.40	...
30	.....	.....	.....	.29	3.78	1.35	.08	.18	.30	.38	.40	...
31	.....	.....	.....	.....	3.60	.....	.05	.17	.....	.38	.....	...

[a] River frozen.

Rating table for Uinta River at Ouray School, near Leland, Utah, for Januar to December 1, 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fee*
−0.2	30	1.0	210	2.2	660	3.4	2,040
− .1	35	1.1	240	2.3	720	3.5	2,200
.0	40	1.2	270	2.4	780	3.6	2,362
.1	54	1.3	300	2.5	850	3.7	2,524
.2	68	1.4	330	2.6	930	3.8	2,686
.3	82	1.5	360	2.7	1,010	3.9	2,848
.4	96	1.6	390	2.8	1,110	4.0	3,010
.5	110	1.7	430	2.9	1,240	4.1	3,172
.6	130	1.8	470	3.0	1,400	4.2	3,334
.7	150	1.9	510	3.1	1,560	4.3	3,496
.8	170	2.0	550	3.2	1,720	4.4	3,658
.9	190	2.1	600	3.3	1,880	4.5	3,820

[a] The daily discharges for December were obtained from the measurements by interpolatio

Estimated monthly discharge of Uinta River at Ouray School, near Leland, Utah.

[Drainage area, 967 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January [a]			110	6,764	0.11	0.13
February [a]			110	6,109	.11	.11
March [a]			100	6,149	.10	.12
April	146	76	92	5,457	.09	.10
May	2,653	84	740	45,484	.77	.89
June	2,120	246	651	39,029	.67	.75
July	327	47	132	8,148	.14	.16
August	65	30	40	2,467	.04	.05
September	470	34	72	4,284	.07	.08
October	94	78	89	5,460	.09	.10
November	154	57	97	5,780	.10	.11
December [a]	104	57	83	5,129	.09	.10
The year	2,653	30	193	140,296	.20	2.70

[a] Jan. 1 to Apr. 1, and Dec. 21-31, river frozen; quantities estimated.

DUCHESNE RIVER AT PRICE ROAD BRIDGE, UTAH.

The station on Duchesne River was established October 26, 1899, and is located 3 miles below the mouth of Lake Creek at the highway bridge on the stage road from Price to Fort Duchesne. The permanent gage rod was placed November 16, 1899, and is nailed to the east side of the center pier. Bench mark No. 1 is a wire nail in a log close to the rod, and is opposite the 7-foot mark. Bench mark No. 2 is a wire nail on the west side of the crib, with an elevation of 5.48 feet above gage datum. The section at this point is very good, with a moderate velocity of water. There is one pier in the center of the stream which does not materially affect the accuracy of the results at low water, but presumably will to a certain extent during the flood season.

Discharge measurements of Duchesne River at Price Road Bridge, Ut

Date.	Hydrographer.	Gage height.	cl
1902.		*Feet.*	*Sec*
March 21	C. T. Prall	5.23	
March 28	do	5.25	
April 4	do	5.32	
April 11	do	5.56	
April 18	do	6.28	
April 25	do	5.93	
May 2	do	6.05	
May 9	do	6.45	
May 16	do	7.50	
May 23	do	6.75	
May 30	do	8.85	
June 6	do	8.30	
June 13	do	7.55	
June 20	do	6.70	
June 27	do	6.20	
July 5	do	6.08	
July 11	Prall and Reed	5.75	
July 19	H. S. Reed	5.50	
July 25	do	5.40	
August 1	do	5.22	
August 9	do	5.12	
August 15	do	5.35	
August 22	do	5.15	
August 29	do	5.22	
September 5	do	5.02	
September 12	do	5.00	
September 19	do	5.10	
September 26	do	5.22	
October 3	do	5.22	
October 10	do	5.22	
October 18	do	5.25	
October 24	do	5.25	
October 31	do	5.25	
November 14	do	5.28	
November 21	do	5.30	
November 28	do	5.35	

Daily gage height, in feet, of Duchesne River at Price Road Bridge, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	(a)	(a)	(a)	5.26	6.05	8.80	6.10	5.20	5.13	5.25	5.28	(a)
2	.....	.....	.....	5.27	6.13	8.25	6.13	5.15	5.10	5.25	5.28	.....
3	.....	.....	.....	5.29	6.18	7.90	6.13	5.18	5.10	5.25	5.28	.....
4	.....	.....	.....	5.30	6.21	7.90	6.14	5.18	5.10	5.25	5.28	.....
5	.....	.....	.....	5.33	6.22	8.05	6.00	5.15	5.10	5.25	5.28	.....
6	.....	.....	.....	5.38	6.24	8.10	6.07	5.13	5.10	5.20	5.28	.....
7	.....	.....	.....	5.39	6.25	8.15	6.03	5.13	5.08	5.20	5.28	.....
8	.....	.....	.....	5.47	6.28	8.25	5.88	5.13	5.00	5.20	5.29	.....
9	.....	.....	.....	5.53	6.48	8.43	5.80	5.10	5.00	5.20	5.28	.....
10	.....	.....	.....	5.56	6.63	8.45	5.75	5.13	4.96	5.20	5.28	.....
11	.....	.....	5.19	5.58	6.80	7.85	5.75	5.15	4.99	5.20	5.30	.....
12	.....	.....	5.20	5.60	7.04	7.60	5.73	5.18	5.00	5.20	5.30	.....
13	.....	.....	5.23	5.63	7.35	7.45	5.70	5.20	5.02	5.20	5.30	.....
14	.....	.....	5.21	5.70	7.33	7.38	5.68	5.45	5.05	5.20	5.30	.....
15	.....	.....	5.25	5.78	7.48	7.35	5.65	5.33	5.05	5.20	5.30	.....
16	.....	.....	5.27	5.85	7.50	7.10	5.65	5.25	5.08	5.20	5.30	.....
17	.....	.....	5.27	5.93	7.60	6.90	5.64	5.18	5.10	5.25	5.30	.....
18	.....	.....	5.26	6.30	7.63	6.75	5.60	5.18	5.10	5.25	5.30	.....
19	.....	.....	5.27	6.46	7.40	6.65	5.50	5.18	5.10	5.25	5.30	.....
20	.....	.....	5.28	6.64	7.25	6.68	5.50	5.18	5.10	5.25	5.32	.....
21	.....	.....	5.21	6.50	7.00	6.57	5.50	5.18	5.38	5.25	5.32	.....
22	.....	.....	5.21	6.21	6.83	6.55	5.50	5.15	5.39	5.28	5.32	.....
23	.....	.....	5.22	5.95	6.70	6.53	5.46	5.15	5.33	5.29	5.32	.....
24	.....	.....	5.22	5.90	6.65	6.50	5.42	5.15	5.35	5.30	5.32	.....
25	.....	.....	5.23	5.93	6.55	6.40	5.40	5.15	5.28	5.30	5.32	.....
26	.....	.....	5.24	6.00	6.80	6.31	5.40	5.15	5.25	5.28	5.32	.....
27	.....	.....	5.25	6.04	7.50	6.20	5.35	5.15	5.25	5.28	5.32	.....
28	.....	.....	5.25	6.08	7.88	6.19	5.33	5.18	5.25	5.28	5.32	.....
29	.....	.....	5.26	5.99	8.53	6.18	5.28	5.20	5.25	5.28	5.32	.....
30	.....	.....	5.24	6.05	8.80	6.14	5.25	5.20	5.25	5.28	5.32	.....
31	.....	.....	5.27	.....	9.20	.....	5.23	5.17	.....	5.28	.....	.....

[a] River frozen.

Rating table for Duchesne River at Price Road Bridge, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
5.0	200	6.4	1,120	7.8	2,840	9.2	5,820
5.2	280	6.6	1,320	8.0	3,160	9.4	6,280
5.4	380	6.8	1,520	8.2	3,550	9.6	6,740
5.6	500	7.0	1,760	8.4	3,980	9.8	7,200
5.8	630	7.2	2,000	8.6	4,440	10.0	7,660
6.0	780	7.4	2,240	8.8	4,900		
6.2	940	7.6	2,520	9.0	5,360		

Estimated monthly discharge of Duchesne River at Price Road Bridge, Utah.

[Drainage area, 2,746 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January [a]	----------	----------	280	17,217	0.10	0.12
February [a]	----------	----------	280	15,550	.10	.11
March [a]	----------	----------	291	17,875	.11	.13
April	1,360	304	656	39,035	.24	.27
May	5,820	820	1,969	121,069	.72	.83
June	4,900	892	2,239	133,235	.82	.91
July	892	292	555	34,138	.20	.23
August	410	240	273	16,804	.10	.12
September	374	184	258	15,364	.09	.10
October	320	280	297	18,288	.11	.13
November	332	312	322	19,152	.12	.13
December [a]	----------	----------	300	18,447	.11	.13
The year	5,820	184	644	466,174	.24	3.21

[a] Jan. 1 to Mar. 10 and Dec. 1-31 river frozen; quantities estimated.

LAKE CREEK AT WAGON BRIDGE (NEAR MOUTH), UTAH.

The permanent gage rod at this place consists of a 1-inch by 4-inch by 8-foot board nailed vertically to the west abutment on the lower side of the wagon bridge near the mouth of the creek. Bench mark No. 1 is a nail in the abutment opposite the 4.50-foot mark on the rod. Bench mark No. 2 is directly over the gage rod, and is the head of a wire nail in the southwest corner of the bridge upright. Its elevation is 5,066.58 feet. The elevation of the zero of the rod is 5,055.99 feet above sea level, according to the hydrographic survey datum. The elevation of bench mark No. 2 is 5,129 feet, referred to the topographic survey datum. The elevation of a regulation iron post bench mark, 150 feet east of the bridge, is 5,127.55 feet, referred to the latter datum. The bed of the stream is composed of medium-sized cobblestones and forms a fair section. During flood stages measurements are made from the bridge, but at other periods they are made by wading at a point about 400 feet below.

Discharge measurements of Lake Creek at wagon bridge (near mouth), Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 21	C. T. Prall	1.86	93
March 28	do	1.92	103
April 4	do	1.92	105
April 11	do	1.90	103
April 18	do	1.90	103
April 25	do	2.00	121
May 2	do	2.04	133
May 9	do	2.33	226
May 16	do	3.20	651
May 23	do	2.70	358
May 30	do	5.85	2,367
June 6	do	4.93	1,735
June 13	do	4.10	1,144
June 20	do	3.10	649
June 27	do	2.70	454
July 5	do	2.55	357
July 11	Prall and Reed	2.30	222
July 19	H. S. Reed	2.25	173
July 25	do	2.05	141
August 1	do	1.95	106
August 9	do	1.92	98
August 15	do	2.06	141
August 22	do	1.89	89
August 29	do	1.93	110
September 5	do	1.80	79
September 12	do	1.80	76
September 19	do	1.85	86
September 26	do	1.95	105
October 3	do	1.92	103
October 10	do	1.90	94
October 24	do	1.92	99
October 31	do	1.90	96
November 14	do	1.90	98
November 21	do	1.93	97
November 28	do	2.50	127
November 28	do	2.50	162
December 5	do	2.00	106
December 13	do	1.82	76

Daily gage height, in feet, of Lake Creek at wagon bridge (near mouth), Uta

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De
1902.												
1	(a)	(a)	(a)					1.95				
2					2.04							
3										1.92		
4				1.92								
5							2.55		1.80			2.
6						4.93						
7												
8											1.89	
9					2.33			1.92				
10										1.90		
11				1.90			2.30					
12									1.80			
13						4.10						1.
14											1.90	(a
15								2.06				
16					3.20							
17												
18				1.90								
19							2.25		1.85			
20			(a)			3.10						
21			1.86								1.93	
22								1.89				
23					2.70							
24										1.92		
25				2.00			2.05					
26									1.95			
27						2.70						
28			1.92								2.50	
29								1.93				
30					5.85							
31										1.90		

a River frozen.

Estimated monthly discharge of Lake Creek at wagon bridge.

[Drainage area, 475 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January [a]			90	5,534	0.19	0.22
February [a]			90	4,998	.19	.20
March [a]			97	5,937	.20	.23
April	130	103	109	6,512	.23	.26
May	2,700	132	718	44,168	1.51	1.74
June	3,000	418	1,238	73,700	2.61	2.91
July	406	110	220	13,500	.46	.53
August	141	89	108	6,650	.23	.27
September	105	76	88	5,232	.18	.20
October	104	94	97	5,994	.20	.23
November	162	96	109	6,512	.23	.26
December [a]			90	5,534	.19	.22
The year	3,000	76	264	184,271	.54	7.27

[a] Jan. 1 to Mar. 15 and Dec. 18 to 31, river frozen; quantities estimated.

NOTE.—The daily discharges were obtained from the discharge measurements by interpolation.

UINTA RIVER AT FORT DUCHESNE, UTAH.

This river, on its emergence from its canyon, spreads out in numerous channels over its flood plain until it reaches a point a short distance above Fort Duchesne, where its waters are collected into one channel. Whiterocks River enters some distance above this point. A number of canals for the use of the Indians divert water between Fort Duchesne and the agency. On the west side are a number of small ditches, which in the aggregate take considerable water; but the amount is difficult to estimate. On the east side are two principal ditches, known as Canal No. 1 and Bench ditch. This station was established September 14, 1899, in connection with the investigation of the water supply for the Uinta Indian Reservation, and is located at the highway bridge at the fort. The permanent rod was established November 8, 1899, and is nailed to the southern end of the east crib of the new bridge. The bench mark is a nail is the southeast crib in the first header above the bottom and is at an elevation of 4,910.13 feet. The elevation of the zero of the rod is 4,907.20 feet.

Discharge measurements of Uinta River at Fort Duchesne, Utah.

Date.	Hydrographer.	Gage height.	Di
1902.		*Feet.*	*Sec*
January 3	C. T. Prall	(a)	
January 9	do		
January 16	do		
February 6	do		
February 13	do		
February 20	do		
February 27	do		
March 7	do	2.70	
March 12	do	2.68	
March 20	do	2.66	
March 26	do	2.70	
April 5	do	2.65	
April 9	do	2.60	
April 16	do	2.54	
April 23	do	2.65	
April 30	do	2.57	
May 7	do	2.72	
May 14	do	3.90	
May 21	do	3.42	
May 28	do	4.33	
June 5	do	4.05	
June 11	do	3.92	
June 18	do	3.35	
June 25	do	3.12	
July 2	do	3.18	
July 9	do	2.88	
July 18	Prall and Reed	2.80	
July 23	H. S. Reed	2.67	
July 30	do	2.50	
August 7	do	2.40	
August 14	do	2.50	
August 21	do	2.36	
August 28	do	2.43	
September 4	do	2.40	
September 11	do	2.30	
September 18	do	2.42	
September 21	do	3.10	
September 25	do	2.55	
October 2	do	2.52	

a Ice.

Discharge measurements of Uinta River at Fort Duchesne, Utah—Continued.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
October 8	H. S. Reed	2.55	67
October 22	do	2.55	70
October 30	do	2.58	66
November 5	do	2.61	77
November 12	do	2.80	151
November 19	do	2.70	114
November 26	do	2.62	65
December 3	do	2.60	56
December 9	do	2.81	105
December 19	do	2.90	83
December 26	do		92

Daily gage height, in feet, of Uinta River at Fort Duchesne, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	(a)	(a)	2.60	2.75	2.60	4.30	3.14	2.45	2.47	2.52	2.58	2.60
2			2.60	2.65	2.62	4.05	3.17	2.43	2.45	2.52	2.58	2.60
3			2.53	2.64	2.65	3.90	3.09	2.41	2.42	2.52	2.55	2.60
4			2.48	2.63	2.68	3.95	3.05	2.40	2.41	2.52	2.59	2.53
5			2.53	2.63	2.72	3.98	3.03	2.40	2.39	2.53	2.60	2.60
6			2.60	2.63	2.75	3.95	3.00	2.40	2.37	2.53	2.60	2.70
7			2.85	2.63	2.75	3.93	2.98	2.40	2.35	2.53	2.60	2.75
8			2.85	2.63	2.85	3.93	2.93	2.40	2.35	2.54	2.62	2.80
9			2.83	2.62	2.99	4.03	2.87	2.40	2.35	2.55	2.62	2.80
10			2.80	2.60	3.26	3.85	2.85	2.38	2.35	2.55	2.62	2.80
11			2.74	2.58	3.48	3.74	2.83	2.37	2.35	2.55	2.73	2.80
12			2.68	2.58	3.74	3.73	2.81	2.50	2.37	2.58	2.78	2.80
13			2.70	2.58	3.68	3.70	2.80	2.50	2.38	2.58	2.67	2.62
14			2.68	2.58	3.85	3.68	2.77	2.50	2.38	2.58	2.68	2.57
15			2.66	2.56	3.94	3.58	2.74	2.48	2.38	2.58	2.68	2.53
16			2.68	2.54	4.00	3.48	2.72	2.45	2.40	2.57	2.64	2.48
			2.68	2.53	4.08	3.42	2.78	2.43	2.40	2.56	2.65	2.48
			2.68	2.54	3.80	3.38	2.79	2.40	2.40	2.56	2.68	2.66
			2.65	2.55	3.60	3.29	2.73	2.40	2.43	2.56	2.70	2.80
			2.65	2.60	3.53	3.25	2.70	2.38	2.45	2.56	2.70	2.80
			2.65	2.70	3.39	3.24	2.70	2.38	2.98	2.56	2.70	(a)
			2.65	2.80	3.31	3.20	2.68	2.35	2.58	2.56	2.70	
			2.65	2.68	3.26	3.17	2.65	2.32	2.52	2.56	2.70	
			2.68	2.66	3.19	3.11	2.63	2.36	2.52	2.56	2.70	
			2.70	2.65	3.30	3.10	2.62	2.38	2.52	2.58	2.70	
			2.70	2.60	3.50	3.10	2.62	2.38	2.52	2.58	2.62	
			2.70	2.60	4.03	3.10	2.59	2.35	2.52	2.58	2.62	
			2.72	2.60	4.48	3.10	2.57	2.43	2.52	2.60	2.62	
			2.65	2.60	4.45	3.11	2.51	2.50	2.52	2.60	2.62	
			2.65	2.58	4.43	3.12	2.50	2.50	2.52	2.60	2.62	
			2.70		4.44		2.47	2.49		2.60		

[a] River frozen.

Rating table for Uinta River at Fort Duchesne, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.3	20	3.2	320	4.1	1,230	5.0	3,064
2.4	40	3.3	370	4.2	1,432	5.1	3,268
2.5	60	3.4	420	4.3	1,636	5.2	3,472
2.6	92	3.5	500	4.4	1,840	5.3	3,676
2.7	126	3.6	580	4.5	2,044	5.4	3,880
2.8	160	3.7	660	4.6	2,248	5.5	4,084
2.9	200	3.8	770	4.7	2,452		
3.0	240	3.9	890	4.8	2,656		
3.1	280	4.0	1,050	4.9	2,860		

Estimated monthly discharge of Uinta River at Fort Duchesne, Utah.

[Drainage area, 672 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall in inches.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1902.							
January [a]	----------	----------	125	7,686	0.19	0.22	1.70
February [a]	----------	----------	130	7,220	.19	.20	.05
March	180	56	118	7,252	.18	.21	.14
April	160	70	98	5,857	.15	.17	.70
May	2,002	92	662	40,703	.99	1.14	.30
June	1,636	280	622	37,012	.93	1.04	.50
July	308	54	158	9,729	.24	.28	.05
August	60	24	43	2,676	.06	.07	.00
September	232	30	54	3,217	.08	.09	1.45
October	92	66	79	4,852	.12	.14	.00
November	153	60	102	6,052	.15	.17	.00
December [a]	----------	----------	85	5,205	.13	.15	.00
The year	2,002	24	190	137,461	.28	3.88	4.89

[a] January 1 to March 1 and December 21 to 31, river frozen; quantities estimated.

NOTE.—Daily discharges from November 26 to December 31 were obtained from the discharge measurements by interpolation.

UINTA RIVER NEAR WHITEROCKS, UTAH.

he fall of 1899 an investigation of the water supply of the ian Reservation was begun by Cyrus C. Babb, and in this a number of gaging stations were established. Uinta rges from its canyon about 10 miles northwest of the Indian Whiterocks, and at this point a gaging station was estab- ember 16, 1899. The gage rod is a 2 by 4 inch timber, 12 bolted to two trees on the left bank of the stream. The k is a nail in an aspen tree 125 feet north of the rod, and n is 8.93 feet above gage datum. During flood stages dis- asurements are made by means of a car and cable, but at tages they are made by wading. The bed of the stream is strewn with large bowlders, and the station is not altogether y, on account of the roughness of the channel. During the velocity undoubtedly will be great, owing to the rapid water. A few hundred yards above the station an impor- ary comes in from the east. At the present location a sec- el has to be measured, but it will never carry a large volume Farther down the stream a number of larger channels are that it is difficult to obtain a satisfactory station.

harge measurements of Uinta River near Whiterocks, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
902.		*Feet.*	*Second-feet.*
	C. T. Prall	0.90	126
	do	.85	144
	do	.90	128
	do	.65	124
	do	.65	123
	do	1.00	160
	do	.75	123
	do	.85	152
	do	.75	126
	do	.90	178
	do	.80	144
	do	.76	129
	do	.92	179
	do	.82	148
	do	.92	179
	do	1.70	538
	do	1.60	507

Discharge measurements of Uinta River near Whiterocks, Utah—Contin

Date.	Hydrographer.	Gage height.	Disc
1902.		*Feet.*	*Seco*
May 26	C. T. Prall	1.73	
June 3	do	2.00	
June 9	do	2.13	
June 16	do	1.75	
June 23	do	1.55	
June 30	do	1.45	
July 7	do	1.30	
July 14	C. T. Prall and H. S. Reed	1.20	
July 21	H. S. Reed	1.10	
July 28	do	1.10	
August 4	do	1.05	
August 11	do	1.05	
August 19	do	1.00	
August 25	do	.97	
September 1	do	1.00	
September 8	do	.95	
September 15	do	.93	
September 22	do	1.00	
September 29	do	.95	
October 6	do	.93	
October 20	do	.93	
October 27	do	.90	
November 3	do	.90	
Do	do	.90	
November 10	do	.90	
November 17	do	.93	
November 24	do	.90	
December 1	do	1.07	
December 17	do	1.28	
December 23	do	.85	
December 30	do	1.50	

Daily gage height, in feet, of Uinta River near Whiterocks, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
									1.00			1.07
			1.00			2.00					0.90	
								1.05				
					0.92							
	0.90									0.93		
				0.80			1.30					
									.95			
						2.13						
		0.90	.75								.90	
								1.05				
					1.70							
	.85											
				.76			1.20					
									.93			
						1.75						
		.65	.85								.93	1.28
					1.60			1.00				
										.93		
				.92			1.10					
									1.00			
						1.55						.85
		.65	.75								.90	
								.97				
					1.73							
										.90		
				.82			1.10					
									.95			
						1.45						1.50
			.90									

Estimated monthly discharge of Uinta River near Whiterocks, Utah.[a]

[Drainage area, 218 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	144	123	136	8,360	0.62	0.71
February	143	123	127	7,083	.58	.60
March	178	123	144	8,837	.66	.76
April	185	129	154	9,164	.71	.79
May	1,200	160	555	34,114	2.55	2.94
June	1,000	379	665	39,579	3.05	3.40
July	430	190	262	16,132	1.20	1.38
August	200	167	181	11,144	.83	.96
September	177	160	167	9,923	.77	.86
October	166	140	152	9,364	.70	.81
November	147	125	139	8,269	.64	.71
December	----------	----------	125	7,686	.57	.66
The year	1,200	123	235	169,655	1.07	14.58

[a] Daily discharges were obtained from the discharge measurements by interpolation.

WHITEROCKS RIVER NEAR WHITEROCKS, UTAH.

A gaging station was established in the canyon of this river about 10 miles above the United States Indian agency at Whiterocks on September 15, 1899, by Cyrus C. Babb, in connection with the investigation of a water supply for the Uinta Indian Reservation. The gage rod consists of a 2 by 4 inch by 12 foot timber bolted to the triple trunk of a tree on the left bank of the stream. The bench mark is a nail in a burnt tree 50 feet east of the rod, and is at an elevation of 10.[illegible] feet above gage datum. During flood stages discharge measurements are made from a car and cable 200 feet above the gage rod. At ordinary stages they are made by wading. The bed of this river is rocky, is strewn with large bowlders, and although permanent in character is not altogether satisfactory because of the fact that it is impossible to obtain accurate soundings.

Discharge measurements of Whiterocks River near Whiterocks, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 7	C. T. Prall	0.80	52
January 14	do	.90	48
February 11	do	.70	39
February 18	do	.75	40
February 25	do	.70	47
March 4	do	1.10	44
March 11	do	.70	47
March 18	do	.70	47
April 1	do	.78	56
April 8	do	.78	54
April 15	do	.72	46
April 22	do	.86	66
April 29	do	.88	66
May 6	do	1.12	101
May 13	do	2.10	429
May 20	do	1.75	293
May 27	do	2.75	851
June 4	do	2.20	490
June 10	do	2.00	425
June 17	do	1.70	276
June 24	do	1.40	169
July 1	do	1.40	166
July 8	do	1.23	133
July 15	Prall and Reed	1.05	91
July 22	H. S. Reed	1.03	77
July 29	do	1.00	78
August 5	do	.97	68
August 12	do	1.00	70
August 18	do	.95	64
August 26	do	.90	63
September 2	do	.93	61
September 9	do	.87	49
September 16	do	.90	51
September 23	do	1.00	67
September 30	do	.90	59
October 7	do	.87	56
October 21	do	.85	51
October 28	do	.83	47
November 4	do	.80	46

Discharge measurements of Whiterocks River near Whiterocks, Utah—Continued.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
November 11	H. S. Reed	0.95	63
November 18	do	.90	48
November 25	do	.78	38
December 2	do	2.15	41
December 18	do	1.92	52
December 24	do	.85	40
December 31	do	.85	39

Daily gage height, in feet, of Whiterocks River near Whiterocks, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1				0.78			1.40					
2									0.93			2.15
3												
4			1.10			2.20					0.80	
5								0.97				
6					1.12							
7	0.80									0.87		
8				.78			1.23					
9									.87			
10						2.00						
11		0.70	.70								.95	
12								1.00				
13					2.10							
14	.90											
15				.72			1.05					
16									.90			
17						1.70						
18		.75	.70					.95			.90	1.92
19												
20					1.75							
21										.85		
22				.86			1.03					
23									1.00			
24						1.40						.85
25		.70									.78	
26								.90				
27					2.75							
28										.83		
29				.88			1.00					
30									.90			
31												.85

ated monthly discharge of Whiterocks River near Whiterocks, Utah.[a]

[Drainage area, 114 square miles.]

nth.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
902.						
.....	54	41	48	2,924	0.42	0.48
.....	47	39	41	2,297	.36	.37
.....	55	44	48	2,955	.42	.48
.....	71	46	57	3,416	.50	.56
.....	1 100	76	471	28,947	4.13	4.77
.....	900	166	348	20,704	3.05	3.40
.....	200	77	109	6,684	.96	1.11
.....	76	62	67	4,094	.59	.68
r	67	49	57	3,410	.50	.56
.....	59	47	53	3,255	.46	.53
r.....	63	38	48	2,830	.42	.47
'.....	52	39	44	2,705	.39	.45
) year	1,100	38	116	84,221	1.02	13.86

r discharges were obtained from the discharge measurements by interpolation.

ASHLEY CREEK NEAR VERNAL, UTAH.

stream drains an area directly east of the Uinta Basin. ½ miles above the town of Vernal the river appears from its and within the next few miles a series of canals divert its er flow, which is applied to the adjacent lands—Vernal Valich are extensively irrigated. A gaging station was estab- the canyon of this stream on March 15, 1900, by C. T. Prall. ated at the ranch of the observer, E. Marett. The gage is a rod, painted white, fastened to the west side of the single he wagon bridge.

ench mark at this station was originally at the 4-foot mark, 20-penny nail driven into the pier at that point, but owing to ing of the upper stringers of the pier the upper fastenings to rod pulled out and the bench mark has dropped one-tenth of o that in the fall of 1902 it was opposite the 3.90-foot mark. 'age readings have not been disturbed as the bottom upon ne lower stringers rests, to which the rod is fastened, is of a 'manent character.

nannel is straight for a distance above and below the bridge bed is rocky. At high stages two other channels discharge n of the water and these also have to be measured.

The three principal canals diverting water from Ashley Creek below the gaging station are, in order downstream, Upper Ashley canal, Rock Point canal, and Central Ashley canal.

Discharge measurements of Ashley Creek near Vernal, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
March 14	C. T. Prall	0.60	46.0
July 16	H. S. Reed	1.00	104.0
November 6	do	.60	43.0
December 12	do	.60	40.0

Daily gage height, in feet, of Ashley Creek near Vernal, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	0.65	0.60	0.60	0.55	1.95	2.80	1.23	0.75	0.70	0.70	0.65	0.60
2	.60	.60	.60	.55	2.55	2.45	1.25	.70	.70	.70	.60	.60
3	.60	.60	.60	.55	2.45	2.35	1.20	.70	.70	.70	.60	.60
4	.60	.60	.60	.55	2.30	2.30	1.20	.70	.70	.70	.60	.60
5	.60	.60	.60	.55	2.20	2.30	1.20	.70	.70	.70	.60	.60
6	.60	.60	.60	.58	2.30	2.20	1.15	.70	.70	.70	.60	.60
7	.60	.60	.60	.60	2.10	2.10	1.15	.70	.65	.70	.60	.60
8	.60	.60	.60	.63	2.30	2.05	1.10	.70	.65	.70	.60	.60
9	.60	.60	.60	.65	2.50	2.03	1.10	.70	.65	.70	.60	.60
10	.60	.60	.60	.65	2.50	1.95	1.10	.70	.65	.70	.60	.60
11	.60	.60	.60	.65	2.60	1.95	1.05	.70	.60	.70	.70	.60
12	.60	.60	.60	.63	2.55	1.90	1.05	.73	.60	.70	.70	.60
13	.60	.60	.60	.60	2.60	1.83	1.00	.75	.60	.70	.65	.60
14	.60	.60	.60	.60	3.05	1.73	1.00	.75	.60	.65	.60	.60
15	.60	.60	.60	.60	2.90	1.68	1.00	.70	.60	.65	.60	.60
16	.60	.60	.55	.60	2.95	1.65	1.00	.70	.60	.65	.60	.60
17	.60	.60	.55	.63	2.85	1.60	1.00	.70	.60	.65	.60	.60
18	.60	.60	.55	.75	2.40	1.55	1.00	.70	.60	.65	.60	.60
19	.60	.60	.55	1.25	2.20	1.50	1.00	.70	.60	.65	.60	.60
20	.60	.60	.55	1.30	2.10	1.45	.95	.70	.70	.65	.60	.60
21	.60	.60	.55	1.10	2.00	1.45	.95	.70	.80	.65	.60	.60
22	.60	.60	.55	.98	1.90	1.38	.90	.70	.75	.65	.60	.60
23	.60	.60	.55	.85	1.80	1.33	.90	.70	.70	.65	.60	.60
24	.60	.60	.55	.80	1.80	1.30	.85	.70	.70	.65	.60	.60
25	.60	.60	.55	.80	1.80	1.30	.85	.70	.70	.65	.60	.60
26	.60	.60	.55	.73	2.25	1.25	.80	.70	.70	.65	.60	.60
27	.60	.60	.55	.83	3.15	1.20	.80	.70	.70	.65	.60	.60
28	.60	.60	.55	.95	3.50	1.20	.80	.70	.70	.65	.60	.60
29	.60	.....	.55	1.40	3.25	1.30	.80	.70	.70	.65	.60	.60
30	.60	.....	.55	1.80	2.95	1.30	.80	.70	.70	.65	.60	.60
31	.60	.....	.55	.....	3.00	.....	.75	.70	.....	.65	.....	.60

Rating table for Ashley Creek near Vernal, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.5	37	1.4	202	2.3	474	3.2	774
.6	45	1.5	230	2.4	506	3.3	810
.7	55	1.6	258	2.5	538	3.4	846
.8	69	1.7	286	2.6	570	3.5	882
.9	85	1.8	315	2.7	602	3.6	918
1.0	106	1.9	346	2.8	636	3.7	954
1.1	128	2.0	378	2.9	670	3.8	990
1.2	152	2.1	410	3.0	704		
1.3	176	2.2	442	3.1	738		

Estimated monthly discharge of Ashley Creek near Vernal, Utah.

[Drainage area, 250 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.		Rainfall, in inches, at Vernal 7½ miles south.
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	
1902.							
January	50	45	45	2,777	0.18	0.21	0.21
February	45	45	45	2,498	.18	.19	.51
March	45	40	42	2,608	.17	.20	.86
April	315	40	78	4,665	.31	.35	.72
May	882	315	533	32,765	2.13	2.46	.42
June	636	152	306	18,226	1.22	1.36	.51
July	164	62	108	6,627	.43	.50	.12
August	62	55	56	3,429	.22	.25	.46
September	69	45	52	3,096	.21	.23	.99
October	55	50	52	3,103	.21	.24	.05
November	55	45	46	2,737	.18	.20	1.12
December	45	45	45	2,767	.18	.21	.97
The year	882	40	117	85,298	.47	6.40	6.94

YAMPA RIVER AT CRAIG, COLO.

This station was established by A. L. Fellows May 25, 1901, at wagon bridge about 1 mile southwest from Craig, Colo., this p being selected as the most suitable station on Yampa River. gage consists of a vertical 2 by 4 inch timber fastened to the s abutment of the bridge on the downstream side, the rod being mar in feet and tenths vertically. The wagon bridge is marked eve feet. The channel is deep at this point, and at low stages the cur is sluggish, but measurements give good results, as the cha changes but little. The observer is H. Jones, of Craig, who r the rod daily.

The following discharge measurements were made during 190 A. J. McCune and J. E. Field:

July 7: Gage height, 3.50 feet; discharge, 987 second-feet.
October 15: Gage height, 2.30 feet; discharge, 243 second-feet.

Daily gage height, in feet, of Yampa River at Craig, Colo.

Day.	Apr.	May.	June.	July.	Aug.	S
1902.						
1	2.60	6.10	7.90	3.60	2.10	
2	2.80	6.80	7.10	3.50	2.00	
3	2.80	7.30	6.80	3.30	2.00	
4	2.90	7.50	7.00	3.40	2.00	
5	2.90	7.70	7.10	3.20	1.90	
6	3.00	7.50	6.90	3.30	1.90	..
7	3.00	7.30	6.90	3.30	1.90	..
8	3.20	7.00	6.90	3.20	1.90	..
9	3.30	7.50	7.00	3.10	1.90	..
10	3.50	7.65	6.70	3.00	1.90	..
11	3.60	7.85	6.50	2.90	1.90	..
12	3.60	7.80	6.40	2.80	1.90	..
13	3.60	7.50	6.20	2.70	1.90	..
14	3.70	7.60	5.90	2.70	1.90	..
15	3.80	7.70	5.60	2.60	1.90	..
16	3.70	7.80	5.30	2.50	1.90	..
17	4.00	8.00	5.10	2.40	1.90	..
18	4.40	7.50	4.90	2.40	1.90	..
19	4.90	7.00	4.70	2.40	1.90	..
20	5.30	6.60	4.50	2.50	1.90	..
21	5.40	6.00	4.30	2.60	1.90	..
22	5.10	5.70	4.10	2.50	1.90	..
23	5.00	5.40	3.90	2.50	1.90	..
24	4.80	5.20	3.90	2.40	1.80	..
25	4.70	5.40	3.70	2.40	1.80	..
26	4.80	5.30	3.60	2.30	1.80	..
27	4.90	7.00	3.40	2.30	1.90	..
28	5.00	7.40	3.30	2.30	1.90	..
29	5.20	7.10	3.60	2.30	2.00	..
30	5.70	7.50	3.60	2.20	2.00	..
31	.....	7.20	.....	2.20	1.90	..

[a] No observer.

Rating table for Yampa River at Craig, Colo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
1.8	90	3.4	906	5.0	2,985	6.6	5,891
2.0	136	3.6	1,081	5.2	3,320	6.8	6,285
2.2	198	3.8	1,285	5.4	3,664	7.0	6,683
2.4	276	4.0	1,520	5.6	4,016	7.2	7,086
2.6	370	4.2	1,780	5.8	4,376	7.4	7,494
2.8	480	4.4	2,058	6.0	4,744	7.6	7,904
3.0	606	4.6	2,352	6.2	5,120	7.8	8,316
3.2	748	4.8	2,662	6.4	5,502	8.0	8,728

Estimated monthly discharge of Yampa River at Craig, Colo.

[Drainage area, 1,730 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	4,195	370	1,797	106,929	1.04	1.16
May	8,728	3,320	6,722	413,320	3.89	4.48
June	8,522	825	3,969	236,172	2.29	2.55
July	1,081	198	479	29,452	.28	.32
August	165	90	115	7,071	.07	.08

GREEN RIVER AT GREENRIVER, WYO.

The gaging station at Greenriver, Wyo., is at the crossing of the Union Pacific Railroad. It was established May 2, 1895, at the pump house of the Union Pacific Railroad Company. The rod is fastened to a pile near the east end of the bridge. The bench mark consists of a cross on the third step from the bottom on the south end of the east abutment, and is 12.48 feet above gage datum. As the section under the railroad bridge is poor, discharge measurements are made from the iron highway bridge about one-half mile below. The station was temporarily discontinued during the latter part of 1900 and for part of 1901.

During 1902 the following discharge measurements were made by A. J. Parshall:

March 31: Gage height, 0.48 feet; discharge, 307 second-feet.
April 9: Gage height, 0.85 feet; discharge, 696 second-feet
April 18: Gage height, 0.98 feet; discharge, 797 second-feet.
May 3: Gage height, 1.15 feet; discharge, 958 second-feet.
May 28: Gage height, 2.20 feet; discharge, 2,244 second-feet.

Daily gage height, in feet, of Green River, at Greenriver, Wyo.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1	0.50	1.15	4.12	3.05	1.75	1.10	0.55	0.45
2	.50	1.15	4.22	3.00	1.70	1.05	.55	.....
3	.50	1.20	4.27	2.95	1.67	1.05	.55	.....
4	.45	1.15	3.90	2.95	1.60	1.05	.55	.....
5	.45	1.10	3.55	2.97	1.55	1.00	.50	.....
6	.53	1.05	3.47	2.97	1.58	1.00	.50	.....
7	.65	1.00	3.55	2.88	1.50	.97	.50	.....
8	.80	1.00	3.67	2.77	1.45	.95	.50	.....
9	.95	1.00	3.77	2.68	1.40	.95	.50	.....
10	1.00	1.03	3.95	2.57	1.35	.90	.50	.....
11	1.00	1.13	4.20	2.48	1.35	.90	.50	.....
12	.95	1.38	4.50	2.32	1.30	.80	.50	.....
13	.90	1.55	4.75	2.23	1.30	.80	.50	.....
14	.90	1.78	4.67	2.12	1.25	.73	.50	.....
15	.95	1.88	4.57	2.10	1.30	.72	.50	.....
16	1.00	2.08	4.48	2.03	1.30	.75	.50	.....
17	.95	2.35	4.25	2.00	1.30	.70	.50	.....
18	.95	2.60	3.95	2.05	1.25	.68	.50	.....
19	1.10	2.77	3.67	2.12	1.25	.65	.50	.....
20	1.25	2.75	3.47	2.15	1.23	.60	.50	.....
21	1.40	2.70	3.33	2.15	1.20	.95	.50	.....
22	1.40	2.55	3.12	2.10	1.20	1.00	.50	.....
23	1.45	2.42	3.07	2.05	1.20	.95	.50	.....
24	1.50	2.33	3.00	2.00	1.80	.75	.50	.....
25	1.48	2.15	3.03	1.95	2.00	.65	.50	.....
26	1.48	2.05	3.13	1.90	2.20	.60	.50	.....
27	1.28	2.08	3.17	1.85	2.20	.60	.45	.....
28	1.20	2.25	3.25	1.85	2.20	.60	.45	.....
29	1.20	2.85	3.25	1.80	1.65	.57	.45	.....
30	1.20	3.60	3.12	1.80	1.10	.55	.45	.....
31	.....	3.98	.....	1.80	1.10	.....	.45	.....

Rating table for Green River at Greenriver, Wyo., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.1	30	1.2	1,055	2.3	2,430	3.4	5,822
.2	90	1.3	1,165	2.4	2,630	3.5	6,188
.3	160	1.4	1,275	2.5	2,860	3.6	6,554
.4	240	1.5	1,385	2.6	3,130	3.7	6,920
.5	330	1.6	1,495	2.7	3,410	3.8	7,286
.6	430	1.7	1,605	2.8	3,700	3.9	7,652
.7	530	1.8	1,720	2.9	4,030	4.0	8,018
.8	635	1.9	1,845	3.0	4,375	4.5	9,848
.9	740	2.0	1,975	3.1	4,725	5.0	11,678
1.0	845	2.1	2,110	3.2	5,090		
1.1	950	2.2	2,260	3.3	5,456		

Estimated monthly discharge of Green River at Greenriver, Wyo.

[Drainage area, 7,450 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April	1,385	285	844	50,153	0.11	0.12
May	7,925	845	2,262	138,845	.30	.35
June	10,763	4,375	7,104	419,990	.95	1.06
July	4,550	1,720	2,673	164,043	.36	.42
August	2,260	950	1,387	85,130	.19	.22
September	950	380	656	38,937	.09	.10
October	380	285	329	20,206	.04	.05

Miscellaneous measurements in the Colorado River drainage basin.

Date.	Hydrographer.	Stream.	Locality.	Discharge.
1902.				*Sec. feet.*
November 19	W. D. Smith	Gila River	Near mouth	25
November 25	do	do	do	836
December 18	do	do	do	2,109
December 24	do	do	do	238
November 14	S. G. Bennett	Imperial Canal	International boundary	374
December 14	W. D. Smith	do	do	494
October 13	J. E. Field	Yampa	Steamboat Springs, Colo	112
October 16	do	Williams Fork	Hamilton, Colo	47
October 11	do	Grand	Near Piney Creek	488
October 13	do	Elk River	Trull, Colo	147
October 14	do	Yampa	Hayden, Colo	235
July 7	A. J. McCune	Williams Fork		136
July 10	do	Snake	Near Dixon	253
October 11	J. E. Field	Rock Creek	Near McCoy's ranch	11
July 13	W. P. Edwards	Lathos Creek	At mouth	15
July 13	do	Taylor River	Clarke's ranch	259
July 13	do	Spring Creek	Near Gunnison, Colo	19
July 14	do	Cebolla	Between Spencer and Dubois	67
July 15	do	Lake Fork	Carr's ranch	171
July 15	do	Pine Creek	Near Gate View	13
July 15	do	Little Blue Creek	At mouth	9
July 15	do	do	Above junction	18
July 15	do	Little Cimarron Creek.	At mouth	16
July 15	do	Cimarron River	At Cimarron, Colo	119
March 21	A. L. Fellows	Mancos River	Mancos	18
July 12	do	do	do	5
July 17	do	Uncompahgre	Fort Crawford, Colo	63

INTERIOR BASIN.

Under this head is comprised the large extent of arid country which includes nearly the whole of Nevada, the northern and western parts of Utah, and small portions of California and Idaho. Having no outlet to the sea, the entire drainage of this vast basin is lost mainly through evaporation from the numerous lakes and sinks in which the waters of the rivers collect.

The largest of the lakes is Great Salt Lake, which receives the waters of that portion of the basin lying in northern Utah and Idaho. Southwestern Utah drains into Sevier Lake. Other important lakes are Humboldt, Pyramid, Winnemucca, Carson, and Walker, all in western Nevada. These lakes receive the basin drainage from Nevada and California. The principal rivers in this section are as follows:

Bear River has its source on the northern slope of the Uinta Mountains in the northeastern part of Utah, and after a circuitous course in which it leaves Utah and enters Wyoming, reenters Utah, appears again in Wyoming, then in Idaho, and reenters Utah, it finally discharges its waters into Great Salt Lake. Considerable irrigation is practiced on certain portions of the river. Logan River empties into Bear River in Cache Valley, Utah. Blacksmith Fork is a tributary of Bear River from the western slope of the Wasatch Range.

Weber River rises in the high country east of the Wasatch Mountains. Passing through that range, it appears in the plains region in the vicinity of Ogden, where, after receiving the waters of Ogden River, it discharges into Great Salt Lake. There are a number of good reservoir sites on its upper tributaries, some of which have been utilized within the last year.

Provo River rises on the western slope of the Uinta Mountains and after receiving a number of tributaries enters what is known as Heber Valley, where considerable irrigation is practiced. After crossing this valley it passes through the Wasatch Mountains in a picturesque canyon, and finally enters Utah Valley, where its summer flow is completely diverted for irrigation purposes. Its flood waters discharge into Utah Lake.

Sevier River drains a large area in the southwestern part of Utah. It flows northerly until it enters Juab County, then makes a short bend and flows southwest into Sevier Lake. San Pitch River joins Sevier River near Gunnison, Utah.

Humboldt River rises in the extreme northeastern part of Nevada and flows in a general westerly and southerly direction, finally entering Humboldt Lake, whence its waters find their way into the Humboldt and Carson Sink. The general direction of the mountain ranges of this basin is north and south, crossed at nearly right

angles by the main Humboldt River. The tributaries flow in the general direction of the mountain ranges, and drain either to the north or to the south. During low stages the water of the river is almost wholly diverted. For the future development of the country recourse must be had to the construction of storage reservoirs. Of its tributaries, the North Fork enters it west of Peko, Nev., and the South Fork enters it about 10 miles below Elko, Nev.

Pine Creek is a tributary from the south and joins it near Palisade, Nev. Marys River is one of the headwater tributaries of the Humboldt.

Walker River is formed by two branches which have their sources across the Nevada-California boundary, in California. It flows north and then takes a sharp bend to the southeast, emptying into Walker Lake.

Carson River has its source on the slopes of the Sierra Nevada in eastern California, and flows northward into the State of Nevada. The East and West forks unite near Genoa, Nev., in Carson Valley. At Empire, 3 miles east of Carson, after having traversed the Upper Carson Valley, it turns to the northeast and enters a deep canyon, through which it flows for several miles, emerging into a second smaller valley a short distance above the town of Dayton. After leaving this valley it passes through two other shorter canyons and through one rather large valley before entering Lower Carson Valley, or Carson Sink Valley, as it is also known, and discharging its waters into the Carson Sink.

The Truckee has its source on the slopes of the Sierra Nevada in eastern California and flows northward, entering Lake Tahoe, which is at an elevation of 6,225 feet and the largest body of fresh water in the United States at this considerable altitude. The area of the lake is 193 square miles. Its outlet is at Tahoe, Cal., from which point Truckee River has a general northward and eastward course, receiving several important tributaries which contribute to its flow. It drains into Pyramid and Winnemucca lakes, which have no outlets. Donner and Prosser creeks are tributaries of Truckee River. Independence Creek discharges into the Little Truckee, a main branch of Truckee River, entering it at Boca, Cal. They drain areas of 31, 56, and 8.5 square miles, respectively, lying to the northwest of Lake Tahoe, in California.

Susan River has its source in the Sierra Nevada in northeastern California, and flowing eastward discharges into Honey Lake—one of the land-locked lakes of the Great Basin—of which it is the principal feeder. A considerable area of land is irrigated from the waters of the river below the gaging station, and during the last ten or twelve years several projects have been started for irrigating other extensive areas by the storage of its waters both above and below the town of *Susanville.*

The following is a list of stations in the Interior drainage basin:

Bear River near Collinston, Utah.
Bear River at Battlecreek, near Preston, Idaho.
Blacksmith Fork at Hyrum, Utah.
Logan River near Logan, Utah.
Weber River near Uinta, Utah.
Provo River near Provo, Utah.
Sevier River near Gunnison, Utah.
San Pitch River near Gunnison, Utah.
Humboldt River near Oreana, Nev.
Humboldt River near Golconda, Nev.
Humboldt River at Palisade, Nev.
Pine Creek at Palisade, Nev.
Humboldt River (South Fork) at Mason's ranch, near Elko, Nev.
Humboldt River near Elko, Nev.
Humboldt River (North Fork) near Elburz station, near Halleck, Nev.
Marys River at Bradley's Home ranch, near Deeth, Nev.
Walker River near Wabuska, Nev.
Walker River (East Fork) at Ross ranch, near Yerington, Nev.
Walker River (West Fork) at upper end of Antelope Valley, near Coleville, Cal.
Carson River near Empire, Nev.
Carson River (East Fork) at Rodenbah's ranch, near Gardnerville, Nev.
Carson River (West Fork) at Woodfords, Cal.
Truckee River at Tahoe, Cal.
Truckee River at Vista, near Reno, Nev.
Truckee River near Mystic, at Nevada-California State line.
Independence Creek below Independence Lake, near Overton, Cal.
Prosser Creek below Prosser Creek Ice Company's dam, near Boca, Cal.
Donner Creek near Donner Ice Company's dam, near Truckee, Cal.
Susan River near Susanville, Cal.

BEAR RIVER NEAR COLLINSTON, UTAH.

The gaging station at Collinston was established July 1, 1889, and is located about 4 miles from the railroad station at Collinston, miles east of the town of Fielding, Utah, and below the headworks of the Bear River canal. The gage consists of a vertical iron rod graduated to tenths of a foot. The bench mark is a nail in an oak post 5 feet west of the gage and 20 feet north of the cable, and is at an elevation of 7.35 feet above gage datum. The equipment consists of cable, a tagged wire, and a boat. The observer is generally the ditch rider of the Bear River Canal Company, who has a house near the station. The banks of the stream are high and the channel is gravelly with bowlders, the water flowing with moderate velocity. At this point it has a slope of 0.55 foot in 600 feet.

During 1902 the following discharge measurements were made by G. L. Swendsen:

July 16: Gage height, 0.40 foot; discharge, 324 second-feet.
July 20: Gage height, 0.30 foot; discharge, 205 second-feet.
August 13: Gage height, 0.40 foot; discharge, 68 second-feet.
August 26: Gage height, 0.45 foot; discharge, 60 second-feet.
December 30: Gage height, 0.51 foot; discharge, 402 second-feet.

Daily gage height, in feet, of Bear River near Collinston, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.70	1.65	1.85	1.65	2.90	3.50	0.40	−0.10	−0.65	0.80	0.80	0.35
2	1.75	1.60	1.75	1.65	2.90	3.60	.30	− .10	− .55	.80	.80	.35
3	1.80	1.60	1.75	1.70	2.90	3.60	.30	− .10	− .20	.80	.80	.40
4	1.80	1.65	1.75	1.75	2.90	3.45	.40	− .10	− .10	.80	.80	.40
5	1.80	1.60	1.65	1.80	2.80	3.30	.40	− .15	− .15	.80	.80	.45
6	1.80	1.55	1.65	1.90	2.70	3.15	.35	− .20	− .20	.80	.80	.50
7	1.80	1.55	1.65	1.90	2.60	3.00	.35	− .25	− .30	.80	.80	.50
8	1.85	1.60	1.65	2.40	2.60	3.00	.35	− .30	− .20	.80	.80	.55
9	1.85	1.75	1.70	3.00	2.70	3.00	.40	− .35	− .30	.40	.80	.60
10	1.80	1.80	1.80	2.90	2.80	3.10	.40	− .35	− .20	1.00	.90	.60
11	1.80	1.85	1.80	2.75	2.90	3.10	.40	− .40	− .20	.30	1.10	.60
12	1.80	1.85	1.75	2.75	3.00	3.10	.40	− .40	− .10	.90	1.20	.80
13	1.75	1.90	1.75	2.75	3.10	3.10	.35	− .40	− .10	.90	1.30	.70
14	1.70	1.90	1.70	2.75	3.15	3.00	.35	− .40	− .10	.90	1.40	.60
15	1.70	1.70	1.70	2.75	3.15	3.00	.40	− .40	− .10	.90	1.50	.50
16	1.70	1.70	1.65	2.70	3.20	2.90	.45	− .45	− 10	.90	.50	.40
17	1.70	1.70	1.65	2.65	3.25	2.80	.45	− .45	.00	.90	.50	.30
18	1.60	1.80	1.70	2.65	3.30	2.60	.40	− .45	.10	.90	.50	.30
19	1.65	1.80	1.70	2.70	3.30	2.50	.30	− .45	.10	.90	.45	.35
20	1.65	1.70	1.80	2.80	3.30	2.35	.30	− .45	.20	.90	.40	.40
21	1.65	1.70	1.75	3.00	3.30	2.20	.25	− .45	.30	.90	.50	.40
22	1.65	1.65	1.80	3.20	3.20	2.10	.20	− .45	.30	.80	.50	.40
23	1.66	1.65	1.80	3.20	3.20	2.00	.15	− .45	.30	.80	.50	.40
24	1.60	1.65	1.75	3.10	3.10	1.90	.10	− .50	.30	.90	.50	.40
25	1.40	1.65	1.70	3.30	3.10	1.80	.20	− .50	.30	.90	.40	.45
26	1.40	1.70	1.70	3.30	3.10	1.70	.20	− .50	.30	.90	.40	.45
27	1.40	2.00	1.70	3.20	3.20	1.60	.10	− .50	.40	.80	.30	.40
28	1.40	1.95	1.70	3.10	3.25	1.40	.10	− .55	.50	.80	.30	.40
29	1.45	.....	1.70	3.00	3.30	.50	.10	− .55	.60	.80	.35	.40
30	1.50	.....	1.70	2.90	3.35	.50	.00	− .60	.70	.80	.35	.40
31	1.65	.....	1.65	.....	3.45	.....	−.10	− .60	.....	.80	.....	.40

Rating table for Bear River near Collinston, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
−0.1	280	0.7	370	2.0	1,470	3.6	3,340
.0	280	.8	410	2.2	1,670	3.8	3,600
.1	280	.9	460	2.4	1,880	4.0	3,860
.2	285	1.0	520	2.6	2,100	4.2	4,140
.3	290	1.2	690	2.8	2,330	4.4	4,420
.4	300	1.4	870	3.0	2,570	4.6	4,700
.5	310	1.6	1,070	3.2	2,820	4.8	5,000
.6	340	1.8	1,270	3.4	3,080	5.0	5,300

Estimated monthly discharge of Bear River near Collinston, Utah.

[Drainage area, 6,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	1,320	870	1,139	70,034	0.19	0.22
February	1,470	1,020	1,191	66,145	.20	.22
March	1,320	1,120	1,191	73,232	.20	.23
April	2,950	1,120	2,176	129,481	.36	.40
May	3,145	2,100	2,656	163,311	.44	.51
June	3,340	310	2,138	127,220	.36	.40
July	305	280	292	17,954	.05	.06
August	280	280	280	17,217	.05	.06
September	370	280	289	17,197	.05	.06
October	520	290	427	26,255	.07	.08
November	970	290	420	24,992	.07	.08
December	410	290	312	19,184	.05	.06
The year	3,340	280	1,043	752,222	.17	2.38

BEAR RIVER AT BATTLECREEK, IDAHO.

This station, established October 11, 1889, is about 10 miles north of the Utah-Idaho boundary line. The station is of considerable importance from the fact that its location is near the Utah-Idaho line, and the measurements there will indicate the volume of water that passes from Idaho into Utah. During 1901 a large canal was completed, appropriating the waters of the Bear about 8 miles below Soda Springs in sufficient quantity to irrigate about 35,000 acres of very fine land in that locality. The original gage consisted of a vertical board nailed to a pile. This was carried away June 30, 1899, but was replaced on August 4 by a wire and weight, readings being made on a horizontal scale. The bench mark for the old gage was a nail in the southeast corner of a house near the gage, about 1.5 feet from the ground and 10.95 feet above gage datum. There are two bench marks to which the present gage is referred. The first is a nail in the bridge floor beam close to the gage, and the second is three nails in the east side of the north post which supports the station cable. Both of these bench marks are 11.118 feet above the gage datum. The station is equipped with a cable and car.

Discharge measurements of Bear River at Battlecreek, Idaho.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 13	George L. Swendsen	1.60	407
February 1	do	1.80	606
March 15	do	1.72	610
April 20	do	3.00	1,803
May 30	do	3.15	1,961
June 12	do	3.40	2,231
June 18	do	2.40	924
July 21	do	1.25	355
August 11	do	1.19	290
September 29	do	1.32	385
October 6	do	1.58	412
November 3	do	1.62	455
December 24	do	1.70	524

Daily gage height, in feet, of Bear River at Battlecreek, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.60	1.60	1.70	1.70	2.75	3.10	2.30	1.20	1.80	1.45	1.70	1.60
2	1.60	1.60	1.70	1.70	2.75	3.10	2.25	1.15	1.80	1.48	1.65	1.60
3	1.60	1.60	1.70	1.70	2.75	3.10	1.95	1.25	1.80	1.50	1.65	1.60
4	1.00	1.60	1.70	1.75	2.70	3.10	1.88	1.15	1.80	1.55	1.65	1.60
5	(a)	1.60	1.70	1.85	2.65	3.10	1.85	1.20	1.80	1.55	1.65	1.60
6	(a)	1.60	1.70	2.15	2.58	3.10	1.85	1.25	1.80	1.60	1.65	1.60
7	(a)	1.60	1.70	2.70	2.50	3.10	1.85	1.30	1.80	1.60	1.65	1.60
8	(a)	1.60	1.70	3.20	2.60	3.10	1.85	1.35	1.70	1.60	1.65	1.60
9	(a)	(a)	1.70	3.00	2.63	3.10	1.83	1.40	1.60	1.60	1.65	1.60
10	(a)	(a)	1.70	2.90	2.65	3.10	1.80	1.45	1.50	1.60	1.65	1.60
11	(a)	(a)	1.70	2.90	2.70	3.15	1.68	1.50	1.40	1.60	1.65	1.60
12	1.60	(a)	1.70	3.00	2.75	3.15	1.65	1.55	1.30	1.60	1.70	1.60
13	1.60	(a)	1.70	3.50	2.75	3.15	1.65	1.60	1.20	1.60	1.70	1.60
14	1.60	(a)	1.70	3.50	2.75	3.15	1.65	1.65	1.10	1.60	1.70	1.60
15	1.60	(a)	1.70	2.88	2.75	3.10	1.65	1.70	1.10	1.60	1.70	1.60
16	1.60	1.65	1.70	2.80	2.80	3.50	1.58	1.80	1.10	1.60	1.70	1.60
17	1.60	1.65	1.70	2.80	2.85	3.25	1.50	1.80	1.10	1.60	1.70	1.60
18	1.60	1.70	1.70	2.83	3.05	2.95	1.48	1.90	1.15	1.60	1.65	1.60
19	1.60	1.65	1.70	2.90	2.95	2.88	1.43	1.90	1.20	1.60	1.60	1.60
20	1.60	1.65	1.70	2.85	2.90	2.78	1.40	1.90	1.27	1.60	1.60	1.60
21	1.60	1.65	1.70	2.90	3.00	2.73	1.40	1.90	1.30	1.60	1.60	1.60
22	1.60	1.65	1.70	2.80	3.00	2.68	1.40	1.90	1.30	1.60	1.60	1.60
23	1.60	1.65	1.70	2.95	3.00	2.63	1.40	1.90	1.30	1.60	1.60	1.60
24	1.60	1.65	1.70	2.90	3.20	2.58	1.37	1.90	1.30	1.60	1.60	1.60
25	1.60	1.65	1.70	3.20	3.15	2.53	1.35	1.90	1.30	1.60	1.60	1.60
26	1.60	1.65	1.70	3.10	3.10	2.43	1.35	1.90	1.30	1.68	1.60	1.60
27	1.60	1.65	1.70	3.00	3.10	2.33	1.35	1.90	1.32	1.70	1.60	1.60
28	1.60	1.65	1.70	2.95	3.10	2.13	1.35	1.90	1.35	1.70	1.60	.....
29	1.60	.....	1.70	2.90	3.10	2.08	1.33	1.90	1.32	1.70	1.60	.....
30	1.60	.....	1.70	2.85	3.10	2.13	1.30	1.95	1.40	1.70	1.60	.....
31	1.60	.....	1.70	.....	3.10	.....	1.27	1.80	.....	1.70	.....	.....

[a] Gage lost.

Rating table for Bear River at Battlecreek, Idaho, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.1	302	1.8	570	2.5	1,130	3.2	1,928
1.2	324	1.9	632	2.6	1,230	3.3	2,060
1.3	350	2.0	700	2.7	1,334	3.4	2,196
1.4	382	2.1	776	2.8	1,442	3.5	2,336
1.5	420	2.2	856	2.9	1,556		
1.6	464	2.3	942	3.0	1,676		
1.7	514	2.4	1,034	3.1	1,800		

Estimated monthly discharge of Bear River at Battlecreek, Idaho.

[Drainage area, 4,500 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	464	464	464	28,530	0.10	0.12
February	514	464	480	26,658	.11	.11
March	514	514	514	31,605	.11	.13
April	2,336	514	1,438	85,567	.32	.36
May	1,928	1,130	1,493	91,801	.33	.38
June	2,336	776	1,570	93,421	.35	.39
July	942	337	493	30,313	.11	.13
August	666	313	508	31,236	.11	.13
September	570	302	406	24,159	.09	.10
October	514	399	467	28,715	.10	.12
November	514	464	485	28,859	.11	.12
December	464	464	464	28,530	.10	.12
The year	2,336	302	732	529,394	.16	2.21

BLACKSMITH FORK AT HYRUM, UTAH.

Six irrigation canals and one large power canal are supplied by this river, and during the irrigation season the entire supply is utilized. The present gaging station was established July 19, 1900, by George L. Swendsen. It is near the tollgate at the mouth of the canyon. Daily readings are made on a vertical gage. The bench mark, a line of red paint on the top of a short cedar post near the north post of the tollgate, is 8.29 feet above gage datum.

Discharge measurements of Blacksmith Fork at Hyrum, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 27	George L. Swendsen	2.80	112
February 24	do	2.90	114
March 17	do	2.92	113
April 29	do	3.05	129
May 19	do	3.28	176
June 23	do	3.05	130
July 7	do	2.99	130
August 4	do	2.90	115
September 16	do	2.78	103
October 13	do	2.85	119
November 24	do	2.80	108
December 21	do	2.78	102

Daily gage height, in feet, of Blacksmith Fork at Hyrum, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	.....	2.80	2.90	3.05	3.00	3.30	2.80	2.90	2.80	2.85	2.90	2.90
2	.....	2.80	2.90	3.05	3.00	3.30	2.80	2.90	2.80	2.85	2.90	2.90
3	.....	2.92	2.90	3.05	3.00	3.30	2.80	2.90	2.80	2.85	2.85	2.90
4	.....	2.92	2.90	3.05	3.00	3.30	2.80	2.90	2.80	2.90	2.85	2.90
5	2.92	2.92	2.90	3.05	3.00	3.30	2.80	2.85	2.80	2.90	2.85	2.90
6	2.92	2.92	2.90	3.05	3.05	3.30	2.80	2.85	2.80	2.90	2.85	2.90
7	2.80	2.80	2.90	3.05	3.05	3.30	2.80	2.80	2.80	2.90	2.85	2.90
8	2.80	2.80	2.90	3.05	3.05	3.30	2.80	2.80	2.80	2.90	2.90	2.90
9	2.80	2.80	2.90	3.05	3.05	3.30	2.80	2.80	2.80	2.95	2.90	2.90
10	2.80	2.80	2.90	3.05	3.05	3.30	2.80	2.80	2.80	2.95	2.90	2.90
11	2.80	2.80	2.90	3.05	3.05	3.30	2.80	2.80	2.80	2.95	2.90	2.90
12	2.80	2.80	2.90	3.05	3.05	2.90	2.80	2.80	2.80	2.95	2.90	2.90
13	2.80	2.90	2.90	3.05	3.05	2.90	2.80	2.80	2.80	2.95	2.90	2.90
14	2.80	2.90	2.90	3.05	3.00	2.90	2.80	2.80	2.80	2.95	2.90	2.90
15	2.80	2.90	2.90	3.05	3.00	3.20	2.80	2.80	2.80	2.90	2.95	2.90
16	2.80	2.90	2.90	3.05	3.00	3.20	2.80	2.80	2.80	2.95	2.95	2.90
17	2.80	2.90	2.90	2.90	2.90	3.10	2.80	2.80	2.85	2.90	2.95	2.90
18	2.80	2.90	2.80	2.90	2.90	3.10	2.80	2.80	2.85	2.90	2.95	2.90
19	2.80	2.90	2.90	2.90	2.90	3.10	2.80	2.80	2.85	2.90	2.90	2.90
20	2.80	2.90	2.90	2.90	2.90	3.00	2.80	2.80	2.85	2.90	2.90	2.90
21	2.80	2.90	2.90	2.90	2.90	3.00	2.80	2.80	2.85	2.90	2.90	2.90
22	2.80	2.90	2.90	2.90	2.90	3.00	2.80	2.80	2.85	2.91	2.90	2.90
23	2.80	2.90	2.80	2.90	2.90	3.00	2.80	2.80	2.85	2.90	2.90	2.90
24	2.80	2.90	2.90	2.90	3.00	2.90	2.80	2.80	2.85	2.90	2.90	2.90
25	2.80	2.90	2.90	3.00	3.00	2.90	2.80	2.80	2.85	2.95	2.85	2.90
26	2.80	2.90	2.90	3.00	3.00	2.90	2.80	2.80	2.85	2.95	2.85	2.90
27	2.80	2.90	2.90	3.00	3.00	2.80	2.90	2.80	2.85	2.95	2.85	2.90
28	2.80	2.90	2.90	3.00	3.00	2.80	2.90	2.80	2.85	2.95	2.85	2.90
29	2.80	.....	2.90	3.00	3.00	2.80	2.90	2.80	2.85	2.90	2.85	2.90
30	2.80	.....	2.90	3.00	3.00	2.80	2.90	2.80	2.85	2.90	2.90	2.90
31	2.80	.....	2.90	.....	3.00	.....	2.90	2.80	.....	2.90	.....	2.90

Rating table for Blacksmith Fork at Hyrum, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.60	100	2.95	116	3.30	192	3.65	374
2.65	102	3.00	120	3.35	216	3.70	401
2.70	104	3.05	124	3.40	241	3.75	429
2.75	106	3.10	128	3.45	267	3.80	457
2.80	108	3.15	135	3.50	293	3.85	485
2.85	110	3.20	147	3.55	320	3.90	514
2.90	112	3.25	169	3.60	347		

Estimated monthly discharge of Blacksmith Fork at Hyrum, Utah.

[Drainage area, 286 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	112	108	109	6,702	0.38	0.[illegible]4
February	112	108	111	6,165	.39	.[illegible]2
March	112	108	112	6,887	.39	.[illegible]5
April	124	112	120	7,140	.42	.[illegible]7
May	124	112	119	7,317	.42	.4[illegible]
June	192	108	146	8,688	.51	.5[illegible]
July	112	108	109	6,702	.38	.4[illegible]
August	112	108	109	6,702	.38	.4[illegible]
September	110	108	109	6,486	.38	.4[illegible]
October	116	110	113	6,948	.40	.4[illegible]
November	116	110	112	6,664	.39	.4[illegible]
December	112	112	112	6,887	.39	.4[illegible]
The year	192	108	115	83,288	.40	5.4[illegible]

LOGAN RIVER NEAR LOGAN, UTAH.

The station on Logan River was established June 1, 1896, and is located in the river canyon about 2 miles east of Logan, Utah. One gage is a vertical iron post, set firmly in the middle of the river's bed and graduated to feet and tenths. A second gage rod is a wooden post driven into the ground near the north bank of the river. The bench mark for both rods is a stone 35 feet northeast of the end of the cable on the north side of the river, and is at an elevation of 14.01 feet above gage datum. It is marked by a cross chiseled on the rock and

by the letters "B. M." in red paint. The equipment consists of a cable and car. Owing to a washout regular daily gage records were not taken during 1902.

Discharge measurements of Logan River near Logan, Utah.

Date.	Hydrographer.	Gage height.	Dicharge.
1902.		*Feet.*	*Second-feet.*
January 27	G. L. Swendsen	1.45	103
February 22	do	1.60	124
March 3	do	1.60	107
April 17	do	1.70	153
April 26	do	1.80	163
May 17	do	3.50	588
June 13	do	4.37	1,056
June 27	do	3.60	598
July 5	do	2.90	284
August 12	do	2.82	198
September 16	do	2.80	191
October 13	do	2.72	178
November 24	do	2.65	171
December 23	do	2.67	165

WEBER RIVER NEAR UINTA, UTAH.

The gaging station on Weber River, established in October, 1899, is located in the canyon 5 miles east of Uinta, on the Union Pacific Railroad, immediately above the narrows known as Devils Gate. The gage is vertical, and is supported from above by a projecting timber placed out of reach of high water. The bench mark consists of a spike driven into the first telegraph pole in the canyon above the gage, and is at an elevation of 17.44 feet above gage datum. The equipment consists of a cable, car, and tagged wire.

Discharge measurements of Weber River near Uinta, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 20	G. L. Swendsen	1.48	113
February 10	do	1.30	121
April 12	do	1.52	166
May 12	do	1.75	339
September 22	do	1.22	79
October 20	do	1.40	162
December 28	do	1.35	112

PROVO RIVER NEAR PROVO, UTAH.

The gaging station on Provo River, established July 27, 1889, is located in the canyon, about 6 miles from Provo and above the head of most of the irrigation canals of Utah Valley. The diversion works of the company which develop power at the mouth of Provo Canyon for electric transmission to the mines west of Provo, are located about 5 miles above the station. The gage is inclined and fastened to stakes set in the ground. The bench mark is a stone firmly bedded in the bank near the wagon road, about 100 feet southwest of the gage. It is marked "B. M." in black paint, and is 6.95 feet above gage datum. The channel is straight for some distance above and below the station. The bed of the river is gravel and not liable to change. The equipment consists of a cable, car, and tagged wire.

Discharge measurements of Provo River near Provo, Utah.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 26	G. L. Swendsen	4.00	204
March 10	do	4.35	230
April 14	do	4.50	395
May 5	do	4.60	414
July 26	do	4.10	202
September 20	do	4.00	172
November 17	do	3.95	165
December 27	do	4.00	178

SEVIER RIVER NEAR GUNNISON, UTAH.

The station, established by Caleb Tanner on June 29, 1900, is at the bridge which crosses the stream 4 miles west of the town of Gunnison. The gage, which is vertical, is nailed to one of the bridge piles. The bench mark consists of a post at the southeast corner of the bridge, marked, in pencil, "U. S. G. S. gage B. M.," and its elevation is 13.23 feet above gage datum. During 1902 the following measurements were made by Caleb Tanner:

May 18: Gage height, 0.88 foot; discharge, 41 second-feet.
August 15: Gage height, 0.62 foot; discharge, 19 second-feet.

Daily gage height, in feet, of Sevier River, near Gunnison, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.00	(a)	1.50	1.32	0.42	0.50	0.80	0.52	0.60	0.55	0.40	0.95
2	2.05	1.82	1.50	1.32	.42	.55	.80	.52	.60	.50	.35	.95
3	2.10	1.82	1.52	1.30	.42	.50	.60	.52	.62	.50	.35	1.05
4	2.10	2.00	1.45	1.30	.42	.50	.60	.57	.60	.50	.35	1.05
5	2.10	2.02	1.40	1.30	.42	.50	.60	.57	.60	.47	.35	1.00
6	2.10	2.27	1.40	1.32	.45	.42	.67	.67	.60	.47	.35	1.00
7	2.05	2.30	1.40	1.32	.55	.42	.60	.67	.60	.45	.35	1.50
8	2.10	2.42	1.40	1.32	.55	.42	.60	.62	.62	.45	.35	1.70
9	2.10	2.42	1.10	1.32	.55	.42	.50	.62	.62	.45	.35	1.70
10	2.15	2.37	1.10	1.35	.60	.40	.50	.62	.62	.45	35	1.55
11	2.10	2.37	1.10	1.35	.70	.40	.50	.62	.62	.45	35	1.60
12	2.10	2.45	1.10	1.35	.80	.40	.50	.62	.62	.45	35	1.60
13	2.10	2.40	1.02	1.25	.80	.40	.50	.62	.62	.45	35	1.55
14	2.10	2.40	1.02	1.20	.97	.40	.50	.62	.62	.50	35	1.60
15	2.10	2.37	1.02	1.20	.97	.42	.50	.60	.62	.50	35	1.65
16	2.05	2.00	1.05	1.15	1.10	.50	.50	.60	.62	.50	37	1.55
17	2.05	2.00	1.20	1.15	1.00	.65	.52	.60	.60	.50	35	1.60
18	2.02	1.97	1.15	1.12	.90	.65	.52	.60	.60	.50	35	1.60
19	2.00	1.90	1.12	1.15	.80	.70	.60	.60	.60	.50	35	1.70
20	2.00	1.85	1.25	1.22	.70	.70	.57	.60	.60	.50	35	1.70
21	2.00	1.82	1.22	1.20	.65	.70	.57	.60	.60	.47	50	1.65
22	2.02	1.77	1.22	1.20	.55	.67	.55	.60	.60	.47	.50	1.65
23	1.92	1.70	1.22	1.15	.50	.62	.52	.60	.60	.47	.50	1.70
24	1.92	1.62	1.12	1.10	.50	.62	.52	.60	.60	.45	90	1.70
25	1.92	1.62	1.22	1.15	.47	.62	.50	.60	.57	.45	90	1.65
26	(a)	1.60	1.25	1.05	.50	.60	.50	.60	.57	.45	75	(a)
27	(a)	1.60	1.25	.70	.50	.60	.50	.60	.60	.45	.80	(a)
28	(a)	1.55	1.55	.47	.42	.60	.50	.60	.60	.45	.85	(a)
29	(a)	.....	1.55	.42	.52	.80	.50	.60	.57	.45	.97	(a)
30	(a)	.....	1.52	.42	.50	.80	.50	.60	.57	.45	.97	(a)
31	(a)	.....	1.45	.....	.50	.....	.52	.....	.....	.45	.....	(a)

a Frozen.

Rating table for Sevier River near Gunnison, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.4	6	1.1	59	1.8	129	2.5	199
.5	11	1.2	69	1.9	139	2.6	209
.6	17	1.3	79	2.0	149	2.7	219
.7	25	1.4	89	2.1	159	2.8	229
.8	33	1.5	99	2.2	169	2.9	239
.9	41	1.6	109	2.3	179		
1.0	49	1.7	119	2.4	189		

Estimated monthly discharge at Sevier River near Gunnison, Utah.

[Drainage area, 3,986 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	De in
1902.						
January	164	139	151	9,285	0.038	
February	194	104	149	8,275	.037	
March	104	51	76	4,673	.019	
April	84	7	65	3,868	.017	
May	59	7	20	1,230	.005	
June	33	6	15	893	.004	
July	33	11	14	861	.004	
August	23	12	17	1,045	.004	
September	19	15	17	1,012	.004	
October	14	8	9	553	.002	
November	46	5	14	833	.004	
December	119	45	100	6,149	.025	
The year	194	5	54	38,677	.014	

Investigations in relation to the amount of seepage in the Sevier River Ba between Panguitch and the Sevier Bridge between Scipio and Juab.

WATER ENTERING THE DIFFERENT VALLEYS.

Date.	Locality.	Source.	Quar
1902.			*Secon*
August 9	Panguitch Valley	Sevier River	
August 10–11	Junction Valley	do	
		East Fork of Sevier River	
		City Creek	
	Total		
August 11	Between Junction and Marysvale.	Sevier River	
		Tenmile Creek	
		Cottonwood Creek	
		Cottonwood Wash Spring	
	Total		

stigations in relation to the amount of seepage in the Sevier River Basin etween Panguitch and the Sevier Bridge between Scipio and Juab—Cont'd.

WATER ENTERING THE DIFFERENT VALLEYS—Continued.

Date.	Locality.	Source.	Quantity.
1902.			*Second-feet.*
gust 11–13	Marysvale Valley	Sevier River	38.0
		Bullion Creek	12.5
		Beaver Creek	2.5
	Total		53.0
gust 13–14	Sevier Valley to Rocky Ford.	Sevier River	47.5
		Clear Creek	7.3
		Monroe Creek	3.9
		Thompsons Creek	.2
		Redbutte and Cottonwood creeks.	.3
		Water Canyon Creek	.3
		Spring Creek	5.3
		Cove Creek	9.5
		Cedar Ridge Creek	.5
	Total		74.8
gust14–15	Rocky Ford to Redmond Ford.	Sevier River	1.5
		Rocky Ford canal	35.0
		Lost Creek	.7
		Salina Creek	7.8
	Total		45.0
gust 15–16	Redmond Ford to Westview Bridge.	Sevier River	15.5
		Westview canal	4.2
		Willow Creek	.5
		Sanpitch River	15.2
	Total		35.4
Do	Westview Bridge to McArty's Ford.	Sevier River	18.7
		Dover canal	10.7
		Warm Creek	2.7
	Total		32.1
ust 16	McArty's Ford to Sevier Bridge.	Sevier River	22.0

Investigations in relation to the amount of seepage in the Sevier River between Panguitch and the Sevier Bridge between Scipio and Juab—Con

AMOUNT OF WATER DIVERTED FOR IRRIGATION IN THE DIFFERENT VAI

Date.	Locality.	Canal or ditch.	Qu
1902.			Seco
August 9	Panguitch Valley	East Panguitch Irrigation Co. canal.	
		Long Canal Co. canal	
		East Bench Co. canal	
		Panguitch Creek	
		Little Creek	
		McEwan ditch	
		Houston ditch	
		Tibb's ditch	
		Orton's ditch	
		Peterson ditch	
		Walley ditch	
		Vaetor ditch	
		Kessler ditch	
		Johnson ditch	
	Total		
August 10–11	Junction Valley	Miscellaneous canals	
		Junction Canal Co. upper ditch	
		Junction Canal Co. middle ditch	
		Junction Canal Co. lower ditch	
		Private ditch	
	Total		
August 11	Between Junction and Marysvale.	Not given	
August 11–13	Marysvale Valley	do	
August 13–14	Sevier Valley to Rocky Ford.	Clear Creek irrigation canal	
		Joseph City irrigation canal	
		Wells irrigation canal	
		Isaacson irrigation canal	
		Monroe irrigation canal	
		Elsinore irrigation canal	
		Brooklin irrigation canal	
		Richfield irrigation canal	
		Anabella irrigation canal	
		Candor irrigation canal	
		Vermilion irrigation canal	
	Total		

Investigations in relation to the amount of seepage in the Sevier River Basin between Panguitch and the Sevier Bridge between Scipio and Juab—Cont'd.

AMOUNT OF WATER DIVERTED FOR IRRIGATION IN THE DIFFERENT VALLEYS—Continued.

Date.	Locality.	Canal or ditch.	Quantity.
1902.			*Second-feet.*
August 14–15	Rocky Ford to Redmond Ford.	Not given	43.5
August 15–16	Redmond Ford to Westview Bridge.	Robbins canal	8.14
		Westview canal	4.20
		Other canals	15.70
	Total		28.04
Do	Westview Bridge to McArty's Ford.	Not given	13.4
August 16	McArty's Ford to Sevier Bridge.		None.

AMOUNT OF WATER LEAVING THE DIFFERENT VALLEYS.

Date.	Locality.	Name of river or canal.	Quantity second-feet.
1902.			
August 10	Panguitch Valley	Sevier River	30.7
August 11	Junction Valley	do	10.7
Do	Between Junction and Marysvale.	do	38.0
August 13	Marysvale Valley	do	47.5
August 14	Sevier Valley to Rocky Ford.	do	1.5
		Rocky Ford and Willow Bend canal.	35.0
	Total		36.5
August 15	Rocky Ford to Redmond Ford.	Sevier River	15.5
		West View canal	4.2
	Total		19.7
Do	Redmond Ford to Westview Bridge.	Sevier River	18.7
		Dover canal	10.7
	Total		29.4
Do	Westview Bridge to McArty's Ford.	Sevier River	22.0
August 16	McArty's Ford to Sevier Bridge.	do	18.5
Do	*Panguitch to Sevier Bridge.*	do	18.5

Investigations in relation to the amount of seepage in the Sevier River Basin between Panguitch and the Sevier Bridge between Scipio and Juab—Cont'd.

RÉSUMÉ.

Date.	Locality.	Quantity of water.				Seepage.
		Entering valley.	Used for irrigation.	Leaving valley.	Leaving valley and used for irrigation.	
1902.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
August 8–10	Panguitch Valley	46.2	68.0	30.7	98.7	52.5
August 10–11	Junction Valley	47.2	53.8	10.7	64.5	17.3
August 11	Between Junction and Marysvale.	17.2	6.5	38.0	44.5	27.3
August 11–13	Marysvale Valley	53.0	15.0	47.5	62.5	9.5
August 13–14	Sevier Valley to Rocky Ford.	74.8	64.36	36.5	100.86	26.06
August 14–15	Rocky Ford to Redmond Ford.	45.0	43.5	19.7	63.2	18.2
August 15–16	Redmond Ford to Westview Bridge.	35.4	28.04	29.4	57.44	22.04
Do	Westview Bridge to McArty's Ford.	32.1	13.4	22.0	35.40	3.3
August 16	McArty's Ford to Sevier Bridge.	22.0	0.0	18.5	18.5	−3.5
August 8–16	Panguitch to Sevier Bridge.	142.1	292.6	18.5	311.1	169.0

SAN PITCH RIVER NEAR GUNNISON, UTAH.

The station, established by Caleb Tanner on June 30, 1900, is 4 miles northeast of the town of Gunnison, at the ranch of the observer, J. P. Jensen. The gage consists of a vertical post driven firmly into the bed of the stream and strongly braced. The bench mark is the top of a cedar post 1 foot in diameter, set firmly in the ground, 44 feet west of the gage rod. Its elevation is 5.96 feet above gage datum. During 1902 the following measurements were made by Caleb Tanner:

May 17: Gage height, 2.28 feet; discharge, 81 second-feet.
August 16: Gage height, 1.79 feet; discharge, 15 second-feet.

Daily gage height, in feet, of San Pitch River near Gunnison, Utah.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.74	1.74	1.74	1.80	2.40	2.30	2.00	1.70	1.75	1.75	1.77	1.70
2	1.74	1.74	1.74	1.80	2.50	2.30	2.08	1.70	1.75	1.75	1.77	1.70
3	1.74	1.74	1.76	1.80	2.60	2.20	2.00	1.70	1.75	1.75	1.70	1.80
4	1.74	1.74	1.76	1.80	2.50	2.20	2.00	1.70	1.75	1.75	1.70	1.80
5	1.74	1.74	1.76	1.80	2.70	2.20	2.00	1.70	1.75	1.75	1.70	1.80
6	1.74	1.76	1.76	1.76	2.70	2.20	2.00	1.80	1.75	1.75	1.70	1.75
7	1.76	1.76	1.76	1.70	2.70	2.20	2.00	1.80	1.75	1.75	1.70	1.75
8	1.76	1.76	1.76	1.90	2.65	2.20	2.00	1.80	1.75	1.75	1.70	1.70
9	1.76	1.76	1.76	1.87	2.60	2.10	2.00	1.80	1.75	1.75	1.70	1.70
10	1.76	1.76	1.76	1.85	2.65	2.10	2.00	1.80	1.75	1.75	1.70	1.70
11	1.76	1.76	1.76	1.80	2.70	2.20	2.00	1.80	1.75	1.75	1.70	1.70
12	1.76	1.76	1.76	1.90	2.75	2.20	2.00	1.75	1.75	1.75	1.70	1.70
13	1.76	1.76	1.76	1.90	2.70	2.10	2.00	1.80	1.75	1.75	1.70	1.70
14	1.76	1.76	1.76	1.90	2.80	2.10	2.00	1.80	1.75	1.75	1.70	1.70
15	1.76	1.76	1.76	1.90	2.40	2.10	2.00	1.80	1.75	1.75	1.70	1.65
16	1.76	1.76	1.76	1.90	2.40	2.15	2.00	1.80	1.75	1.75	1.70	1.65
17	1.76	1.76	1.76	1.97	2.30	2.15	2.00	1.70	1.75	1.75	1.70	1.65
18	1.76	1.76	1.76	2.00	2.30	2.15	2.10	1.70	1.75	1.75	1.70	1.65
19	1.76	1.76	1.76	2.20	2.30	2.10	2.10	1.70	1.75	1.75	1.70	1.70
20	1.76	1.76	1.76	2.10	2.20	2.10	2.10	1.80	1.75	1.75	1.70	1.70
21	1.76	1.76	1.76	2.20	2.20	2.00	2.00	1.80	1.85	1.75	1.70	1.70
22	1.76	1.74	1.76	2.10	2.10	2.20	2.00	1.80	1.85	1,75	1.70	1.70
23	1.76	1.74	1.76	2.00	2.10	2.10	2.00	1.80	1.80	1.75	1.70	1.70
24	1.76	1.74	1.76	2.20	2.20	2.12	1.90	1.80	1.75	1.75	1.70	1.70
25	1.76	1.74	1.76	2.20	2.20	2.00	1.90	1.80	1.75	1.75	1.70	1.70
26	1.76	1.74	1.76	2.30	2.30	2.00	1.80	1.80	1.75	1.77	1.70	1.70
27	1.76	1.74	1.76	2.30	2.30	2.00	1.76	1.80	1.75	1.77	1.70	1.70
28	1.76	1 74	1.76	2.30	2.40	2.10	1.70	1.80	1.75	1.77	1.70	1.70
29	1.76	.....	1.76	2.30	2.30	2.10	1.70	1.80	1.75	1.77	1.70	1.70
30	1.76	.....	1.76	2.40	2.30	2.10	1.70	1.80	1.75	1.77	1.70	1.70
31	1.76	.....	1.76	.....	2.30	.....	1.70	1.75	.....	1.77	.....	1.70

Rating table for San Pitch River near Gunnison, Utah, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.70	10	1.92	27	2.14	57	2.36	89
1.72	11	1.94	30	2.16	59	2.38	92
1.74	12	1.96	32	2.18	62	2.40	95
1.76	13	1.98	34	2.20	65	2.42	98
1.78	14	2.00	37	2.22	68	2.44	101
1.80	15	2.02	40	2.24	71	2.46	104
1.82	17	2.04	43	2.26	74	2.48	107
1.84	19	2.06	45	2.28	77	2.50	110
1.86	21	2.08	48	2.30	80		
1.88	23	2.10	51	2.32	83		
1.90	25	2.12	54	2.34	86		

Estimated monthly discharge of San Pitch River near Gunnison, Utah.

[Drainage area, 836 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep inc
1902.						
January	13	12	13	799	0.02	
February	13	12	13	722	.02	
March	13	12	13	799	.02	
April	95	10	40	2,380	.05	
May	155	51	101	6,210	.12	
June	80	37	54	3,213	.06	
July	51	10	33	2,029	.04	
August	15	10	14	861	.02	
September	21	13	14	833	.02	
October	15	13	13	799	.02	
November	15	10	10	595	.01	
December	15	7	10	615	.01	
The year	155	7	27	19,855	.03	

HUMBOLDT RIVER NEAR OREANA, NEV.

On the lower reaches of this river measurements have been m for a number of years near Oreana, and the results show the amo of water available for storage at the possible reservoir sites in vicinity of Humboldt station, and also for the six canal systems i in operation below Oreana. The station established by L. H. Tay January 27, 1896, was located at the old Oreana highway bridge, at 12 miles northeast of Lovelocks, Nev. The bridge abutment to wh the gage was fastened was undermined and fell May 26, 1897. A t porary gage was used until September 8, 1897, when a new incli one was placed on the left bank of the river about a mile and a above the sight of the old gage and opposite the C. P. Railroad sec house.

This gage was washed out and a new vertical gage, in two pa was placed November 29, 1902, by E. C. Murphy. The gage spiked to piles at the site of the old dam, the zero of the old and gages coinciding. The bench mark is four nails driven into pile which the upper part of the gage is fastened. Its elevation is 5 above the zero of gage. The channel here is straight for about feet above the gage and for about 150 feet below. The station is vided with a cable and car. The river banks are high and not li to overflow. The bed of the stream is sandy and shifting. observer is G. A. Sapp.

During 1902 the following discharge measurements were made by E. C. Murphy and D. W. Hays:

July 23: Gage height, 1.75 feet; discharge, 251 second-feet.
October 17: Gage height, 0.17 foot; discharge, 22 second-feet.

Daily gage height, in feet, of Humboldt River near Oreana, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec
1902.												
1	0.70	0.80	0.90	1.10	1.00	1.00	2.20	1.30	0.20	0.50	0.40	0.50
2	.70	.90	.80	1.10	1.00	1.30	2.00	1.20	.10	.50	.40	.40
3	.70	.90	.80	1.20	1.00	1.50	1.90	1.30	.10	.60	.40	.40
4	.80	1.00	.90	1.20	.90	1.70	1.90	1.30	.10	.60	.40	.50
5	.80	1.00	1.00	1.20	.70	1.80	2.10	1.20	.20	.60	.30	.60
6	.80	1.20	1.00	1.20	.60	1.60	2.20	1.20	.30	.60	.30	.40
7	.90	1.30	.90	1.20	.40	1.60	2.40	1.10	.30	.40	.30	(a)
8	.90	1.30	1.00	1.20	.40	1.50	2.60	1.10	.30	.30	.30	(a)
9	1.00	1.60	1.00	1.10	.50	1.40	2.70	1.00	.40	.30	(a)	(a)
10	1.00	1.40	.90	1.10	.60	1.10	2.50	.90	.40	.30	(a)	(a)
11	1.10	1.40	1.00	1.00	.60	.80	2.30	1.00	.60	.20	(a)	(a)
12	1.10	1.20	1.00	1.00	.50	.60	2.20	1.00	.60	.30	(a)	(a)
13	1.30	1.20	1.00	1.00	.60	.60	2.20	.90	.60	.30	(a)	(a)
14	1.20	1.00	1.00	1.00	.70	.50	2.10	.80	.60	.40	(a)	.20
15	1.00	.90	1.00	1.20	.70	.50	2.10	.80	.60	.40	(a)	.20
16	1.00	.90	1.00	1.20	.70	.50	2.00	.70	.40	.30	.20	.20
17	.90	.80	1.00	1.20	.60	.60	2.00	.70	.40	.30	.20	.10
18	.90	.80	1.00	1.30	.60	.80	1.90	.70	.40	.20	.30	.10
19	.90	.80	1.10	1.30	.50	.80	1.80	.80	.50	.20	.30	.20
20	1.00	.70	1.10	1.30	.50	1.00	1.70	.70	.50	.20	.20	.20
21	1.00	.70	1.10	1.20	.30	1.30	1.90	.70	.50	.30	.20	.20
22	1.20	.60	1.10	1.10	.30	1.30	1.80	.60	.30	.30	.20	.20
23	1.20	.70	1.10	1.10	.10	1.50	1.80	.60	.30	.20	.20	.10
24	1.30	.70	1.10	1.00	.10	1.60	1.80	.60	.40	.10	.20	.10
25	1.40	.70	1.20	1.00	.20	1.70	1.70	.60	.40	.10	.30	.20
26	1.40	.80	1.20	1.00	.30	1.60	1.70	.50	.30	.10	.30	.30
27	1.10	.90	1.20	1.00	.50	1.60	1.60	.50	.30	.20	.50	.30
28	1.00	.90	1.10	1.00	.60	1.70	1.40	.50	.40	.30	.50	.30
29	1.00	.....	1.10	1.00	.70	1.70	1.40	.40	.40	.30	.50	.30
30	.90	.....	1.10	.90	.90	2.00	1.40	.40	.50	.40	.50	.30
31	.80	.....	1.10	.....	1.00	.....	1.30	.40	.....	.40	.....	.20

Rating table for Humboldt River near Oreana, Nev.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.1	19	0.8	69	1.5	168	2.2	333
.2	24	.9	80	1.6	187	2.3	364
.3	29	1.0	92	1.7	207	2.4	397
.4	35	1.1	105	1.8	229	2.5	432
.5	42	1.2	119	1.9	252	2.6	470
.6	50	1.3	134	2.0	277	2.7	511
.7	59	1.4	150	2.1	304	.....	.....

[a] *Only two gagings were made at this station during 1902 and this table is but approximate, being constructed from these and the discharge curve for the year 1901.*

Estimated monthly discharge of Humboldt River near Oreana, Nev.

[Drainage area, 13,800 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	De in
1902.						
January	150	59	94	5,780	0.007	
February	187	50	91	5,054	.007	
March	119	69	96	5,903	.007	
April	134	80	107	6,367	.008	
May	92	19	52	3,197	.004	
June	277	42	137	8,152	.010	
July	511	134	276	16,970	.020	
August	134	35	75	4,612	.005	
September	50	19	35	2,083	.003	
October	50	19	32	1,968	.002	
November	42	24	30	1,785	.002	
December	50	19	28	1,722	.002	
The year	511	19	88	63,593	.006	

HUMBOLDT RIVER NEAR GOLCONDA, NEV.

The gaging station at Golconda is located near the great nort bend of Humboldt River and below the central valley. It is abo miles above the mouth of Little Humboldt River. The station established by L. H. Taylor October 24, 1894, and has been mainta continuously since that time. It is located 1¼ miles north of the t The new inclined gage, installed November 28, 1902, by E. C. Mur is fastened to the left bank by 4 by 4 inch stakes. The zeros of th and new gages are at the same elevation. The bench mark is by 4 inch timber driven 4 feet north of the cable post on the left b at an elevation of 10.75 feet above the zero of the gage. Meas ments are made from a cable and suspended car. The banks moderately high, but liable to overflow at extreme high water. bed of the stream is of gravel and sand and is somewhat shifting

During 1902 the following discharge measurements were mad E. C. Murphy and D. W. Hays:

July 24: Gage height, 2.40 feet; discharge, 218 second-feet.
October 16: Gage height, —0.16 foot; discharge, 1.2 second-feet.

Daily gage height, in feet, of Humboldt River near Golconda, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.10	1.10	1.70	2.20	2.80	3.15	4.30	1.60	0.60	0.40	−0.10	+0.10
2	1.05	1.10	1.70	2.30	2.75	3.15	4.20	1.50	.50	.30	−.10	.00
3	1.00	1.15	1.70	2.20	2.70	3.20	4.25	1.40	.40	.20	−.15	.00
4	1.00	1.15	1.80	2.25	2.70	3.25	4.20	1.35	.35	.20	−.15	.00
5	1.05	1.20	1.90	2.30	2.75	3.30	4.15	1.30	.40	.15	−.20	−.10
6	1.00	1.20	2.00	2.30	2.75	3.30	4.10	1.35	.40	.10	−.15	−.10
7	1.05	1.15	2.00	2.30	2.80	3.35	4.00	1.40	.50	.05	−.10	−.10
8	1.10	1.10	1.90	2.35	2.90	3.35	3.90	1.50	.40	.00	−.10	.00
9	1.20	1.10	2.00	2.35	2.90	3.40	3.80	1.40	.30	−.05	−.10	.00
10	1.30	1.10	2.00	2.30	3.00	3.40	3.70	1.30	.20	−.10	−.15	.10
11	1.40	1.15	2.10	2.35	3.10	3.45	3.60	1.20	.10	−.20	−.10	.10
12	1.50	1.20	2.05	2.40	3.15	3.50	3.50	1.25	.20	−.10	−.10	.15
13	1.60	1.20	2.00	2.50	3.20	3.55	3.30	1.20	.30	−.10	−.10	.15
14	1.60	1.30	2.10	2.60	3.20	3.60	3.20	1.10	.35	.00	−.10	.15
15	1.60	1.40	1.90	2.70	3.15	4.00	3.10	1.00	.10	−.10	.00	.10
16	1.50	1.50	1.90	2.70	3.15	4.10	2.95	.90	.00	−.20	.00	.10
17	1.50	1.50	1.90	2.60	3.10	4.15	2.75	.80	.00	−.10	.10	.00
18	1.40	1.60	1.90	2.65	3.20	4.20	2.70	.70	.00	−.20	.10	.10
19	1.40	1.60	2.00	2.70	3.20	4.25	2.70	.60	.00	−.20	.15	.10
20	1.30	1.65	2.00	2.50	3.15	4.25	2.60	.50	.90	−.20	.15	.10
21	1.30	1.60	2.10	2.60	3.15	4.30	2.65	.40	.90	−.15	.10	.10
22	1.40	1.60	2.10	2.60	3.20	4.30	2.50	.30	.80	−.15	.10	.20
23	1.30	1.50	2.10	2.70	3.20	4.35	2.50	.10	.70	−.10	.10	.30
24	1.20	1.60	2.10	2.70	3.15	4.30	2.40	.20	.60	−.10	.10	.30
25	1.10	1.65	2.00	2.60	3.20	4.35	2.40	.25	.65	.00	.15	.40
26	1.10	1.60	2.15	2.60	3.15	4.30	2.30	.30	.70	.10	−.10	.40
27	1.15	1.65	2.00	2.70	3.20	4.30	2.20	.35	.75	.15	−.15	.50
28	1.10	1.70	2.10	2.75	3.20	4.35	2.10	.40	.60	.20	−.20	.60
29	1.10	.....	2.15	2.75	3.20	4.30	1.90	.50	.50	.15	−.10	.60
30	1.00	.....	2.10	2.80	3.15	4.30	1.80	.55	.40	.10	−.10	.70
31	1.00	.....	2.15	.....	3.15	.....	1.70	.60	.....	.00	.....	.80

Rating table for Humboldt River near Golconda, Nev., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
−0.2	0.8	2.2	139	4.6	584	7.0	1,400
.0	3.0	2.4	162	4.8	635	7.2	1,495
.2	8.0	2.6	188	5.0	688	7.4	1,594
.4	14.0	2.8	217	5.2	743	7.6	1,700
.6	22.0	3.0	248	5.4	802	7.8	1,815
.8	30.0	3.2	283	5.6	865	8.0	1,943
1.0	40.0	3.4	320	5.8	931	8.2	2,088
1.2	52.0	3.6	359	6.0	1,000	8.4	2,256
1.4	66.0	3.8	400	6.2	1,073	8.6	2,451
1.6	82.0	4.0	443	6.4	1,149	8.8	2,675
1.8	99.0	4.2	488	6.6	1,228	9.0	2,935
2.0	118.0	4.4	535	6.8	1,311	9.2	3,235

Estimated monthly discharge of Humboldt River near Golconda, Nev.

[Drainage area, 10,780 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth, in inches.
1902.						
January	82	40	56	3,443	0.0052	0.0060
February	90	46	65	3,610	.0060	.0062
March	134	90	117	7,194	.0109	.0126
April	217	139	177	10,532	.0164	.0183
May	283	202	258	15,864	.0239	.0276
June	523	273	413	24,575	.0383	.0427
July	511	90	282	17,339	.0262	.0302
August	82	5	38	2,337	.0035	.0040
September	35	3	16	952	.0015	.0017
October	14	1	4	246	.0004	.0005
November	6	1	3	179	.0003	.0003
December	30	2	8	492	.0007	.0008
The year	523	1	120	86,763	.0111	.1509

HUMBOLDT RIVER AT PALISADE, NEV.

This station was established November 27, 1902, by E. C. Murphy. It is located at Palisade, Nev. The gage is a plain staff graduated to feet and tenths, located about an eighth of a mile downstream from the cable from which the measurements are made. The gage is read daily by J. O. Brooks. The channel is straight for 200 feet above and 300 feet below the station. The banks are both high. The bed of the stream is permanent. The bench mark is a spike and three nails driven in the timber to which the gage is fastened. Its elevation is 7 feet above the zero of the gage.

Daily gage height, in feet, of Humboldt River at Palisade, Nev.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.			1902.			1902.			1902.		
1		1.35	9		1.55	17		1.50	25		1.55
2		1.35	10		1.55	18		1.50	26		1.55
3		1.30	11		1.55	19		1.45	27	1.35	1.60
4		1.50	12		1.60	20		1.40	28	1.40	1.55
5		1.50	13		1.55	21		1.40	29	1.45	1.50
6		1.55	14		1.50	22		1.45	30	1.35	1.45
7		1.55	15		1.45	23		1.50	31		1.55
8		1.55	16		1.40	24		1.55			

PINE CREEK AT PALISADE, NEV.

This station was established November 27, 1902, by E. C. Murphy. It is located at the railway bridge 1 mile southwest of Palisade, Nev. The gage is a plain staff graduated to feet and tenths, spiked to the right abutment of the railroad bridge. It is read daily by J. O. Brooks. The channel both above and below the station is straight. The banks are high and liable to overflow only at very high water. The bed of the stream is permanent and is composed of gravel and sand. The bench mark is a spike and three nails driven into the timber to which the gage is fastened. Its elevation is 7 feet above the zero of the gage.

A measurement was made October 14, 1902, by E. C. Murphy, which showed a discharge of 7.2 second-feet.

Daily gage height, in feet, of Pine Creek at Palisade, Nev.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.			1902.			1902.			1902.		
1		1.40	9		1.40	17		1.70	25		1.35
2		1.35	10		1.45	18		1.70	26		1.40
3		1.80	11		1.40	19		1.80	27		1.35
4		1.35	12		1.45	20		1.75	28	1.80	1.85
5		1.40	13		1.40	21		1.50	29	1.45	1.70
6		1.45	14		1.50	22		1.75	30	1.45	1.45
7		1.45	15		1.60	23		1.35	31		1.80
8		1.40	16		1.65	24		1.30			

HUMBOLDT RIVER (SOUTH FORK) AT MASON'S RANCH NEAR ELKO, NEV.

The station, established August 29, 1896, by L. H. Taylor, is located 10 miles southwest of the town of Elko and about 6 miles above the junction of the South Fork with the main stream. The gage is inclined and spiked to posts driven firmly into the right bank. A new inclined gage was placed by E. C. Murphy November 22, 1902. It is at the site of the old one, the 4-foot marks of old and new gages coinciding. The bench mark is a 4 by 4-inch timber driven 4 feet south of the gage. It is 6.29 feet above gage datum. The measurements are made from a cable and suspended car at a point 1 mile above the gage, the latter being placed near the farm of the observer, for his convenience. At the point of measurement the banks are high, and the channel is straight for some distance above and below the station. The bed of the stream is of rock and gravel and quite stable. There is a good site for a reservoir a short distance above the station.

In 1902 the following discharge measurement was made by E. C Murphy:

October 12: Gage height, 0.50 feet; discharge, 12 second-feet.

Daily gage height, in feet, of Humboldt River (South Fork) at Mason's ranc near Elko, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	De
1902.												
1	0.75	0.75	0.95	1.30	2.60	2.95	3.10	1.30	0.65	0.30	1.00	1.
2	.75	.80	.95	1.30	2.60	3.00	2.90	1.30	.65	.30	1.00	1.
3	.75	.80	.95	1.40	2.60	3.00	2.90	1.10	.65	.35	1.00	1.
4	.75	.90	.95	1.40	2.70	3.50	2.80	1.10	.65	.35	1.00	1.
5	.70	.90	.95	1.40	2.70	3.50	2.75	1.10	.65	.35	1.10	1.
6	.70	.95	.95	1.90	2.80	4.10	2.50	1.00	.60	.35	1.10	1.
7	.70	.95	.95	1.95	2.80	4.40	2.50	1.00	.50	.40	1.10	1.
8	.70	.95	.95	1.95	2.70	4.50	2.35	1.00	.45	.40	1.10	1.
9	.70	.90	1.10	2.00	2.90	5.00	2.35	1.00	.30	.40	1.10	1.
10	.70	.90	1.10	2.00	2.90	5.10	2.20	1.00	.30	.40	1.10	1.
11	.70	.90	1.10	2.00	3.00	5.20	2.20	1.00	.30	.40	1.10	1.
12	.70	.90	1.10	2.10	3.00	5.40	2.20	1.00	.30	.50	1.20	1.
13	.70	.90	1.10	2.20	3.10	5.70	2.30	.90	.35	.50	1.20	1.
14	.70	.90	1.10	2.20	3.10	5.70	2.25	.90	.25	.55	1.20	1.
15	.70	.90	1.10	2.35	3.10	5.10	2.25	.90	.25	.55	1.20	1.
16	.70	.90	1.10	2.35	3.20	5.00	2.10	.90	.20	.60	1.20	1.
17	.70	.90	1.10	2.35	3.30	4.60	2.10	.80	.20	.65	1.20	1.
18	.70	.90	1.15	2.50	3.10	4.50	2.00	.80	.15	.65	1.20	1.
19	.70	.90	1.15	2.60	3.10	4.50	2.00	.80	.10	.70	1.20	1.
20	.70	.90	1.15	2.80	2.80	4.50	1.90	.70	.10	.70	1.20	1.
21	.70	.90	1.20	2.80	2.75	4.50	1.90	.70	.20	.70	1.20	1.
22	.70	.90	1.20	2.80	2.75	4.50	1.80	.70	.20	.70	1.20	1.
23	.70	.95	1.20	2.80	2.60	4.40	1.75	.70	.20	.75	1.10	1.
24	.70	.95	1.20	2.75	2.60	4.40	1.75	.70	.25	.75	1.10	1.
25	.70	.95	1.20	2.75	2.70	4.10	1.75	.70	.25	.80	1.10	1.
26	.75	.95	1.20	2.75	2.80	3.90	1.75	.70	.25	.90	1.20	1.
27	.75	.95	1.25	2.70	3.00	3.90	1.50	.70	.25	.90	1.20	1.
28	.75	.95	1.25	2.70	3.40	3.90	1.50	.70	.25	1.00	1.20	1.
29	.75	.....	1.25	2.70	3.60	3.40	1.40	.70	.25	1.00	1.20	1.
30	.75	.....	1.30	2.60	3.90	3.20	1.40	.70	.30	1.00	1.20	1.
31	.75	.....	1.30	.....	3.90	.....	1.40	.65	.....	1.00	.....	1.

Rating table for Humboldt River (South Fork), at Mason's ranch, Nevada, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
0.4	7	2.0	276	3.6	740	5.2	1,230
.6	24	2.2	327	3.8	801	5.4	1,292
.8	47	2.4	382	4.0	862	5.6	1,354
1.0	74	2.6	439	4.2	922	5.8	1,416
1.2	105	2.8	499	4.4	983	6.0	1,478
1.4	141	3.0	559	4.6	1,045		
1.6	182	3.2	619	4.8	1,106		
1.8	227	3.4	679	5.0	1,168		

ated monthly discharge of Humboldt River (South Fork) at Mason's ranch, near Elko, Nev.

[Drainage area, 1,150 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
y	41	35	37	2,275	0.032	0.037
ary	67	41	61	3,388	.053	.055
	122	67	92	5,657	.080	.092
	499	122	349	20,767	.304	.339
	831	439	550	33,818	.478	.551
	1,385	544	959	57,064	.834	.934
	589	141	313	19,246	.272	.314
t	122	30	59	3,628	.051	.059
ıber	30	0	7	417	.006	.007
r	74	2	29	1,783	.025	.029
ıber	105	74	96	5,712	.083	.093
ber	122	105	119	7,317	.103	.119
The year	1,385	0	223	161,072	.193	2.629

HUMBOLDT RIVER NEAR ELKO, NEV.

station at Elko, established June 17, 1895, by L. H. Taylor is d at the highway bridge 1 mile southwest of the town. The is inclined, fastened to iron bolts driven into the solid rock, and ced on the left bank immediately below the bridge. The bench is on the southwest corner of the cofferdam surrounding the pier of the bridge, 80 feet north of the gage, and is at an eleva- f 7.50 feet above gage datum. The right bank is quite low; the high and rocky. The bed of the stream is of gravel and sand, a slight tendency to change during flood stages.

The following discharge measurement was made in 1902 by E. C. Murphy.

October 11: Gage height, 1.80 feet; discharge, 1.1 second-feet.

Daily gage height, in feet, of Humboldt River near Elko, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.										
1	1.85	2.50	3.00	2.86	4.30	3.70	3.50	2.20	1.70	1.70
2	1.85	2.50	3.00	2.87	4.25	3.78	3.53	2.15	1.70	1.70
3	1.85	2.50	2.90	2.88	4.10	4.00	3.45	2.15	1.70	1.70
4	1.85	2.50	2.85	2.90	4.10	4.30	3.40	2.15	1.70	1.70
5	1.87	2.40	2.85	2.90	4.00	4.50	3.35	2.15	1.70	1.70
6	1.87	2.40	2.80	2.90	3.90	4.75	3.45	2.15	1.70	1.70
7	1.87	2.50	2.75	2.95	3.80	4.95	3.65	2.00	1.70	1.70
8	1.87	2.40	2.75	3.00	3.75	4.90	3.55	2.00	1.70	1.70
9	1.87	2.50	2.75	3.20	3.75	4.95	3.45	1.90	1.70	1.70
10	1.87	2.50	2.75	3.25	3.60	5.00	3.30	1.90	1.70	1.70
11	1.87	2.40	2.76	3.35	3.60	5.20	3.20	1.90	1.70	1.70
12	2.50	2.40	2.77	3.40	3.65	5.25	3.20	2.00	1.70	1.70
13	2.50	2.50	2.78	3.40	3.75	5.35	3.15	1.90	1.70	1.70
14	2.50	2.50	2.79	3.35	3.80	5.50	3.00	1.90	1.70	(a)
15	2.50	2.60	2.80	3.30	3.85	5.70	2.95	1.90	1.70	.....
16	2.50	2.50	2.80	3.25	3.90	5.65	2.90	1.90	1.70	.....
17	2.50	2.50	2.80	3.28	3.95	5.65	2.85	1.80	1.70	.....
18	2.50	2.50	2.75	3.10	4.00	5.60	2.75	1.80	1.70	.....
19	2.50	2.50	2.80	3.10	4.10	5.65	2.73	1.80	1.70	.....
20	2.50	2.50	2.85	3.20	4.20	5.70	2.75	1.80	1.70	.....
21	2.60	2.60	2.90	3.35	4.25	5.75	2.70	1.75	1.70	.....
22	2.50	2.60	2.90	3.40	4.30	5.60	2.65	1.75	1.70	.....
23	2.40	2.50	2.80	3.50	4.40	5.00	2.60	1.70	1.70	.....
24	2.50	2.60	2.85	4.00	4.30	4.65	2.50	1.70	1.70	.....
25	2.50	2.70	2.90	4.10	4.30	4.20	2.45	1.70	1.70	.....
26	2.50	2.80	3.00	4.40	4.30	4.00	2.43	1.70	1.70	.....
27	2.50	2.90	2.95	4.80	4.25	3.90	2.40	1.70	1.70	.....
28	2.40	3.00	2.90	4.70	4.25	3.75	2.35	1.70	1.70	.....
29	2.40	.....	2.87	4.65	3.60	3.65	2.35	1.70	1.70	.....
30	2.30	.....	2.85	4.60	3.60	5.55	2.30	1.70	1.70	.....
31	2.40	.....	2.85	.....	3.60	.....	2.25	1.70	.....	.....

[a] Discontinued on account of dam backing water up.

Rating table for Humboldt River near Elko, Nev., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.6	0.5	3.0	190	4.8	743	6.6	1,550
1.7	1.0	3.2	240	5.0	822	6.8	1,655
1.8	7.0	3.4	292	5.2	903	7.0	1,763
1.9	14.0	3.6	346	5.4	988	7.2	1,873
2.0	22.0	3.8	402	5.6	1,076	7.4	1,986
2.2	43.0	4.0	461	5.8	1,166	7.6	2,101
2.4	70.0	4.2	525	6.0	1,257	7.8	2,218
2.6	104.0	4.4	594	6.2	1,352	8.0	2,339
2.8	144.0	4.6	667	6.4	1,449		

Estimated monthly discharge of Humboldt River near Elko, Nev.

[Drainage area, 2,840 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	104	10	57	3,505	0.0197	0.023
February	190	70	96	5,332	.0338	.035
March	190	134	153	9,408	.0539	.062
April	743	155	322	19,160	.1134	.126
May	594	346	460	28,284	.1620	.187
June	1,143	332	767	45,640	.2701	.301
July	360	50	187	11,498	.0658	.076
August	43	1	14	861	.0049	.006
September	1	1	1	60	.0004	.0004
October 1 to 14	1	1	1	28	.0004	.0002

HUMBOLDT RIVER (NORTH FORK) NEAR HALLECK, NEV.

This station was established October 10, 1902, by E. C. Murphy. It is located about 2 miles west of the Southern Pacific Railroad station at Elburz. The nearest post-office is Halleck, Nev. The gage is an inclined 4 by 4 inch timber graduated to read direct to feet and tenths. It is read daily by the observer, Joe Dolce. The measurements are taken from a car and cable. The channel is straight both above and below the station. The current is swift. Both banks are high. The left bank overflows at very high water. The bed of the stream is permanent and composed of gravel and silt. The bench mark is a 4 by 4 inch timber driven into the ground about 20 feet upstream from the cable. Its elevation is 6.99 feet above the zero of the gage.

Daily gage height, in feet, of the Humboldt River (North Fork) near Halleck, Nev.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	2.20	2.40	12	2.00	2.30	2.50	23	2.10	2.20	2.60
2	.....	2.10	2.50	13	2.00	2.20	2.60	24	2.20	2.20	2.60
3	.....	2.10	2.50	14	2.00	2.20	2.50	25	2.20	2.10	2.50
4	.....	2.20	2.40	15	2.00	2.30	2.60	26	2.20	2.10	2.60
5	.....	2.30	2.50	16	2.00	2.20	2.60	27	2.20	2.30	2.60
6	.....	2.20	2.40	17	2.00	2.30	2.55	28	2.10	2.40	2.60
7	.....	2.20	2.50	18	2.10	2.30	2.60	29	2.20	2.40	2.70
8	.....	2.30	2.60	19	2.10	2.30	2.50	30	2.10	2.40	2.70
9	.....	2.20	2.50	20	2.10	2.30	2.50	31	2.10	.....	2.70
10	1.90	2.20	2.60	21	2.10	2.30	2.40				
11	1.90	2.30	2.60	22	2.20	2.30	2.50				

MARYS RIVER AT BRADLEY'S HOME RANCH, NEAR DEETH, NEV.

This station is located on Bradley's ranch at the wagon bridge about 20 miles upstream from the mouth or from Deeth, Nev. The gage is a vertical staff graduated to feet and tenths, and is spiked to the pier of the bridge. It is read twice daily by George Murry. The channel is straight both above and below the station. The banks are high and the bed of the stream is composed of silt and clay. The bench mark is a 4 by 4 inch timber set on the left bank 35 feet from the gage. Its elevation is 9.28 feet above the zero of the gage.

A measurement October 10, 1902, by E. C. Murphy showed no discharge.

Daily gage height, in feet, of Marys River near Deeth, Nev.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.			1902.			1902.			1902.		
1	.....	2.30	9	.....	2.40	17	.....	2.45	25	2.40	2.40
2	.....	2.35	10	.....	2.40	18	.....	2.40	26	2.50	2.45
3	.....	2.45	11	.....	2.40	19	.....	2.55	27	2.30	2.40
4	.....	2.40	12	.....	2.40	20	.....	2.45	28	2.25	2.40
5	.....	2.30	13	.....	2.40	21	.....	2.45	29	2.35	2.50
6	.....	2.40	14	.....	2.40	22	.....	2.50	30	2.40	2.40
7	.....	2.40	15	.....	2.30	23	.....	2.45	31	.....	2.40
8	.....	2.40	16	.....	2.45	24	2.45	2.30			

WALKER RIVER NEAR WABUSKA, NEV.

This station was established July 22, 1902, by L. H. Taylor. It was equipped December 12, 1902, by E. C. Murphy. It is located about 2 miles east of Wabuska, Nev. The gage is a vertical staff graduated to feet and tenths and located about 50 feet upstream from the cable, from which measurements are made. The gage is read twice daily by W. H. Mitchell. The channel is straight both above and below the station. The banks are high. The bed of the stream is sandy and shifting. The bench mark is four nails driven in the northwest corner of the pump platform 35 feet east of the gage. The elevation of the bench mark is 6.94 feet above the zero of the gage.

ng 1902 the following discharge measurements were made by Murphy and L. H. Taylor:

ıly 22: Gage height, 1.00 foot; discharge, 47 second-feet.
:tober 7: Gage height, 0.48 foot; discharge, 0.71 second-foot.

Daily gage height, in feet, of Walker River near Wabuska, Nev.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.						
		0.60	0.20	0.20	0.60	1.30
		.55	.20	.20	.60	1.30
		.50	.20	.20	.60	1.30
		.50	.20	.25	.55	1.35
		.45	.20	.25	.55	1.40
		.40	.20	.25	.55	1.40
		.40	.20	.30	.60	1.50
		.40	.20	.30	.65	1.70
		.40	.20	.30	.65	1.70
		.40	.20	.30	.70	1.70
		.40	.15	.30	.70	1.75
		.40	.15	.30	.80	1.75
		.40	.15	.30	.90	1.75
		.40	.15	.30	1.00	1.80
		.40	.15	.30	1.00	1.90
		.40	.15	.30	1.00	1.90
		.35	.15	.30	1.00	1.85
		.35	.15	.30	1.05	1.85
		.30	.15	.30	1.15	1.80
		.30	.20	.30	1.30	1.80
		.30	.20	.30	1.40	1.75
	1.00	.30	.20	.30	1.40	1.75
	.85	.30	.20	.30	1.40	1.75
	.80	.30	.15	.30	1.40	1.70
	.75	.30	.15	.30	1.40	1.70
	.70	.25	.15	.35	1.40	1.65
	.60	.25	.20	.35	1.40	1.65
	.60	.25	.20	.35	1.40	1.60
	.60	.25	.20	.40	1.35	1.55
	.60	.25	.20	.45	1.30	1.45
	.60	.25		.60		1.40

:R RIVER (EAST FORK) AT ROSS RANCH, NEAR YERINGTON, NEV.

station was established October 6, 1902, by E. C. Murphy. It :ed about 10 miles southeast of Yerington, Nev., at Ross ranch. ge is a 4 by 4 vertical timber graduated to feet and tenths. It is ıily by I. A. Strosnider, the ranch owner, who lives about 200 ıway. Measurements are made from a cable. The channel is ıt both above and below the station. The banks are low and :o overflow at high water. The bed of the stream is sand and ıd is liable to shift. The bench mark is three nails driven in ımp of a tree 6 inches in diameter and 15 feet east of the gage. *vation is 5.85 feet above* the zero of the gage.

The following discharge measurement was made in 1902 by E. C. Murphy:

October 6: Gage height, 1.20 feet; discharge, 55 second-feet.

Daily gage height, in feet, of Walker River (East Fork) at Ross ranch, near Yerington, Nev.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	1.70	1.85	12	1.50	1.80	1.80	23	1.60	1.80	1.80
2	.....	1.70	1.90	13	1.50	1.80	1.80	24	1.60	1.80	1.80
3	.....	1.70	1.90	14	1.50	1.80	1.80	25	1.70	1.80	1.80
4	.....	1.70	2.00	15	1.60	1.80	1.80	26	1.70	1.80	1.80
5	.....	1.70	2.00	16	1.60	1.80	1.80	27	1.70	1.80	1.80
6	1.30	1.80	2.10	17	1.60	1.80	1.80	28	1.70	1.80	1.80
7	1.50	1.80	2.10	18	1.60	1.80	1.80	29	1.70	1.80	1.80
8	1.40	1.80	2.10	19	1.60	1.80	1.80	30	1.70	1.80	1.80
9	1.50	1.80	2.10	20	1.60	1.80	1.80	31	1.70	.....	1.80
10	1.50	1.80	2.10	21	1.60	1.80	1.80				
11	1.50	1.80	1.80	22	1.60	1.80	1.80				

WALKER RIVER (WEST FORK) AT UPPER END OF ANTELOPE VALLEY, NEAR COLEVILLE, CAL.

This station was established October 5, 1902, by E. C. Murphy. It is located about 4 miles southwest of Coleville, Cal. The gage is a plain staff graduated to feet and tenths. It is located about one-half mile upstream from the cable from which the measurements are made. The observer is John Trumble. The channel is straight both above and below the station. Both banks are high. The bed of the stream is stony and permanent. The bench mark is a spike driven into the tree to which the gage is fastened. Its elevation is 6 feet above the zero of the gage.

During 1902 the following discharge measurements were made by L. H. Taylor and D. W. Hays:

July 25: Discharge, 331 second-feet.
September 23: Discharge, 32 second-feet.
October 4: Discharge, 70 second-feet.

Daily gage height, in feet, of Walker River (West Fork) near Coleville, Cal.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	1.30	1.30	12	1.00	1.50	1.10	23	1.00	1.30	[illegible]
2	.....	1.20	1.20	13	1.00	1.20	1.00	24	1.20	1.20	[illegible]
3	.....	1.20	1.20	14	1.00	1.20	1.30	25	1.20	1.20	[illegible]
4	.....	1.20	1.30	15	1.00	1.20	1.20	26	1.20	1.30	[illegible]
5	1.10	1.20	1.40	16	1.00	1.30	1.30	27	1.20	1.30	[illegible]
6	1.10	1.20	1.30	17	1.00	1.20	1.10	28	1.30	1.10	[illegible]
7	1.10	1.20	1.30	18	1.00	1.30	1.00	29	1.30	1.30	[illegible]
8	1.10	1.20	1.30	19	1.00	1.20	1.00	30	1.30	1.30	[illegible]
9	1.00	1.20	1.30	20	1.00	1.30	1.00	31	1.30	.....	
10	1.00	1.50	1.30	21	1.00	1.40	1.20				
11	1.00	1.50	1.20	22	1.00	1.40	1.20				

CARSON RIVER NEAR EMPIRE, NEV.

)ctober 21, 1900, a gaging station was established about 2 miles the town of Empire. The old gage, a temporary one, was verlriven into the stream bed, and spiked to a timber set firmly in t bank. The bench mark was on a stone wall 10 feet from the nd at an elevation of 7.5 feet above gage datum. The channel ight, the banks are rather high at the old station, and the bed is sed of cobbles and gravel and is not likely to shift. On Feb-18, 1901, erosion of a bar in the channel above the gage caused ion of the stream bed into two channels. On March 13, 1901, a nent gage was placed farther downstream where the banks are table. The gage consists of a wooden rod driven vertically into eam bed and spiked to a cottonwood tree on the left bank. The mark is on the top of a large bowlder 10 feet north of the gage, vation being 8.38 feet above the datum of the gage.

Discharge measurements of Carson River near Empire, Nev.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
.....	C. V. Taylor	3.10	925
2	D. W. Hays	2.80	755
.....	C. V. Taylor	3.70	1,391
.....	D. W. Hays	2.15	413
.....	do	.35	23
t 30	L. L. Richards	.45	32

Daily gage height, in feet, of Carson River near Empire, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1	1.60	1.60	2.10	1.90	2.50	3.80	2.30	0.30	0.30	0.20	1.60	
2	1.60	1.60	2.00	1.90	2.50	3.60	2.30	.40	.30	.20	1.50	
3	1.60	1.60	2.20	1.90	2.50	3.30	2.20	.40	.30	.20	1.50	
4	1.70	1.60	2.40	2.00	2.40	3.10	2.10	.40	.20	.20	1.40	
5	1.70	1.60	2.40	2.00	2.50	3.10	2.00	.30	.30	.20	1.30	
6	1.70	1.60	2.70	2.00	2.70	3.10	1.90	.30	.20	.20	1.20	
7	1.70	1.60	2.70	2.30	2.90	3.20	1.80	.20	.20	.20	1.10	
8	1.70	1.60	2.70	2.90	3.10	3.30	1.60	.20	.20	.20	1.00	
9	1.60	1.60	2.80	3.00	3.50	3.50	1.50	.20	.20	.20	1.00	
10	1.60	1.60	2.40	2.70	3.70	3.70	1.40	.10	.20	.20	1.00	
11	1.60	1.60	2.00	2.60	3.70	3.70	1.40	.10	.20	.20	1.00	
12	1.60	1.60	1.90	2.40	3.70	3.80	1.40	.10	.20	.30	1.10	
13	1.50	1.80	1.90	2.40	3.70	3.80	1.50	.20	.20	.30	1.10	
14	1.50	1.70	1.90	2.50	3.70	3.60	1.40	.30	.20	.40	1.20	
15	1.50	1.70	1.90	2.60	3.40	3.50	1.20	.30	.10	.40	1.20	
16	1.60	1.70	1.90	2.70	3.30	3.40	1.10	.30	.10	.50	1.20	
17	1.60	1.70	1.90	2.80	3.30	3.20	1.10	.30	.20	.50	1.20	
18	1.60	1.70	2.00	3.00	3.10	3.10	1.00	.30	.10	.60	1.20	
19	1.60	1.70	2.00	3.10	3.30	3.00	1.00	.30	.20	.60	1.40	
20	1.60	1.70	1.90	3.30	3.10	3.00	.90	.30	.20	.60	1.40	
21	1.50	1.70	1.90	3.30	2.90	3.00	.70	.30	.20	.60	1.40	
22	1.50	1.70	1.90	2.80	2.70	3.00	.60	.30	.10	.70	1.40	
23	1.50	1.70	1.90	2.60	2.70	2.90	.50	.30	.10	.70	1.40	
24	1.50	1.70	1.90	2.50	2.70	2.70	.40	.30	.20	.80	1.40	
25	1.50	1.70	1.80	2.50	2.90	2.60	.40	.30	.20	.90	1.40	
26	1.30	1.70	1.80	2.40	3.20	2.60	.40	.30	.20	1.00	1.40	
27	1.30	2.50	1.80	2.30	3.50	2.60	.40	.20	.20	1.10	1.40	
28	1.20	2.30	1.80	2.30	3.70	2.40	.40	.20	.20	1.20	1.40	
29	1.30	.....	1.80	2.30	3.90	2.30	.40	.30	.20	1.40	1.40	
30	1.40	.....	1.80	2.30	4.00	2.30	.30	.30	.20	1.40	1.40	
31	1.50	.....	1.80	.....	3.90	.....	.30	.30	.....	1.50	.....	

Rating table for Carson River near Empire, Nev., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharg
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
0.1	10	1.1	116	2.1	416	3.1	938
.2	15	1.2	137	2.2	457	3.2	1,008
.3	20	1.3	160	2.3	500	3.3	1,082
.4	25	1.4	185	2.4	545	3.4	1,160
.5	32	1.5	212	2.5	592	3.5	1,242
.6	41	1.6	241	2.6	642	3.6	1,328
.7	52	1.7	272	2.7	695	3.7	1,418
.8	65	1.8	305	2.8	751	3.8	1,512
.9	80	1.9	340	2.9	810	3.9	1,610
1.0	97	2.0	377	3.0	872	4.0	1,712

Estimated monthly discharge of Carson River near Empire, Nev.

[Drainage area, 988 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
ary	272	137	225	13,835	0.228	0.26
uary	592	241	279	15,495	.282	.29
h	751	305	411	25,271	.416	.48
	1,082	340	618	36,774	.626	.70
	1,712	545	1,041	64,009	1.054	1.22
	1,512	500	1,002	59,623	1.014	1.13
	500	20	170	10,453	.172	.20
st	25	10	19	1,168	.019	.02
mber	20	10	15	893	.015	.02
ber	212	15	54	3,320	.055	.06
mber	241	97	160	9,521	.162	.18
nber	241	185	213	13,097	.216	.25
The year	1,712	10	351	253,459	.355	4.81

SON RIVER (EAST FORK) AT RODENBAH'S RANCH, NEAR GARDNERVILLE, NEV.

ie gaging station was established by L. H. Taylor on October 17, , at the place where measurements were made in the years 1890, , and 1892. The old gage was an inclined timber securely fast- to posts set in the right bank of the stream. The old bench was on a basalt rock in the edge of the stream, 20 feet from the and at an elevation of 6.3 feet above gage datum. The channel e old station is straight and the banks are high. The stream is of cobbles and gravel, and is quite stable.

August 2, 1901, a loose-rock dam was raised a short distance w the gaging station, which affected the velocity at the latter t. The dam was partly washed out by a freshet on December 4,

A new gage was established on March 10, 1901, a short distance istream from the original one, which had been destroyed. It ists of a vertical timber driven into the stream bed at the right and spiked to a cottonwood tree. A bench mark was also estab- d on a large granite bowlder 20 feet south of the gage under the from which the measurements are made. Its elevation is 8.10 above the datum of the gage. On October 3, 1902, a new inclined was installed by E. C. Murphy at a point on the left bank of the *600 feet above the cable.* This gage has not been read, as the

one placed on March 10, 1901, is still in use. The bench mark is on a rock 2 feet east of the gage. It is 9.945 feet above gage datum.

Discharge measurements of Carson River (East Fork) near Gardnerville, Nev.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 21	D. W. Hays	4.50	514
May 13	C. V. Taylor	5.12	1,138
July 2	D. W. Hays	4.25	486
July 19	do	3.80	192
July 29	do	3.70	139
August 5	C. V. Taylor	3.50	100
September 9	L. L. Richards	3.00	60
October 3	E. C. Murphy	3.20	66

Daily gage height, in feet, of Carson River (East Fork) near Gardnerville, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.30	3.10	3.10	3.80	4.40	4.90	3.80	3.50	3.35	3.05	2.95	3.40
2	3.30	3.10	3.20	3.80	4.40	5.00	4.00	3.60	3.30	2.95	3.00	3.35
3	3.30	3.20	3.10	3.80	4.50	5.20	3.90	3.40	3.10	3.15	2.90	3.30
4	3.30	3.20	3.20	3.80	4.50	5.30	3.90	3.25	3.10	3.10	2.90	3.40
5	3.30	3.20	3.10	3.90	4.60	5.40	3.90	3.40	3.05	3.05	3.00	3.30
6	3.40	3.20	3.10	3.90	4.80	5.50	4.00	3.50	3.00	2.95	3.00	3.30
7	3.30	3.10	3.20	4.90	5.00	5.70	3.80	3.40	3.10	3.10	2.90	3.35
8	3.40	3.20	3.20	4.80	5.20	6.00	3.70	3.60	3.15	3.05	2.90	3.30
9	3.40	3.40	3.40	4.70	5.50	5.40	3.80	3.70	3.05	3.00	3.55	3.30
10	3.30	3.30	3.40	4.40	5.80	5.30	3.90	3.95	3.20	3.10	4.00	3.35
11	3.60	3.20	3.40	4.30	5.20	5.30	3.80	3.75	3.10	3.10	3.75	3.25
12	3.50	3.30	3.40	4.40	5.40	5.40	3.90	3.80	3.05	3.00	3.70	3.30
13	3.50	3.30	3.40	4.40	5.50	5.50	3.80	3.90	3.00	3.10	3.55	3.25
14	3.50	3.30	3.40	4.50	5.50	5.40	3.80	3.85	3.20	2.95	3.50	2.90
15	3.40	3.50	3.50	4.60	5.40	5.50	3.70	3.70	3.15	2.90	3.45	2.90
16	3.50	3.70	3.60	4.60	5.40	5.00	3.80	3.70	3.15	2.95	3.40	2.80
17	3.50	3.60	3.60	4.80	5.50	4.60	3.90	3.75	3.20	3.00	3.25	2.80
18	3.50	3.50	3.60	4.90	4.90	4.70	3.80	3.65	3.00	2.90	3.35	2.80
19	3.40	3.50	3.60	4.70	5.00	4.80	3.80	3.70	2.90	2.90	3.40	2.85
20	3.50	3.50	3.60	4.70	5.20	4.50	3.80	3.70	2.90	2.95	3.35	2.80
21	3.40	3.40	3.70	4.50	5.20	4.60	3.70	3.80	2.85	3.00	3.30	2.75
22	3.50	3.40	3.70	4.30	5.30	4.70	3.70	3.80	2.80	3.20	3.30	2.70
23	3.50	3.30	3.70	4.50	5.60	4.30	3.80	3.65	2.80	3.05	3.40	2.65
24	3.40	3.30	3.60	4.30	5.30	4.20	3.70	3.65	2.75	3.05	3.35	2.6[illegible]
25	3.10	3.30	3.50	4.60	5.50	4.20	3.60	3.50	2.80	2.95	3.40	2.6[illegible]
26	2.90	3.30	3.50	4.50	5.40	4.10	3.70	3.50	2.85	2.90	3.40	2.5[illegible]
27	3.00	3.20	3.60	4.50	5.30	4.00	3.60	3.45	2.90	2.90	3.25	2.6[illegible]
28	3.10	3.10	3.60	4.30	6.00	4.00	3.50	3.50	3.05	2.85	3.35	2.5[illegible]
29	3.20	.....	3.70	4.40	5.50	3.90	3.70	3.45	3.00	2.90	3.35	2.5[illegible]
30	3.20	.....	3.80	4.30	5.40	3.80	3.60	3.45	3.00	3.00	3.40	2.5[illegible]
31	3.20	.....	3.80	.....	5.20	.....	3.60	3.40	.....	2.95	.....	2.4[illegible]

Rating table for Carson River (East Fork) near Gardnerville, Nev., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.5	30	3.4	85	4.3	519	5.2	1,200
2.6	34	3.5	98	4.4	598	5.3	1,275
2.7	38	3.6	115	4.5	675	5.4	1,350
2.8	42	3.7	140	4.6	750	5.5	1,425
2.9	46	3.8	180	4.7	825	5.6	1,500
3.0	51	3.9	233	4.8	900	5.7	1,575
3.1	57	4.0	297	4.9	975	5.8	1,650
3.2	65	4.1	368	5.0	1,050	5.9	1,725
3.3	74	4.2	441	5.1	1,125	6.0	1,800

Estimated monthly discharge of Carson River (East Fork) at Rodenbah ranch, near Gardnerville, Nev.

[Drainage area, 381 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth, in inches.
1902.						
anuary	115	46	81	4,980	0.213	0.25
ebruary	140	57	78	4,332	.205	.21
arch	180	57	101	6,210	.265	.31
pril	975	180	601	35,762	1.577	1.76
ay	1,800	598	1,205	74,093	3.163	3.64
une	1,800	180	955	56,826	2.507	2.80
uly	297	98	178	10,945	.467	.54
ugust	265	70	131	8,055	.344	.40
eptember	80	40	54	3,213	.142	.16
ctober	65	44	51	3,136	.134	.15
ovember	297	46	86	5,117	.226	.25
ecember	85	28	54	3,320	.142	.16
The year	1,800	28	298	215,989	.782	10.63

CARSON RIVER (WEST FORK) AT WOODFORDS, CAL.

The gaging station, established by L. H. Taylor on October 18, 1900, about three-fourths of a mile above the post-office at Woodfords. he gage is a vertical timber graduated to feet and tenths. It is read ily by *Bernice Merrill, Woodfords,* Cal. The channel at the station

is straight, the banks are high and rocky, and the bed is of rock and gravel and not likely to shift. Measurements are made from a car suspended on a steel cable across the stream.

Discharge measurements of Carson River (West Fork) at Woodfords, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
April 22	D. W. Hays	3.65	182
May 13	C. V. Taylor	4.70	422
July 3	D. W. Hays	3.40	158
July 30	do	2.50	47
August 6	C. V. Taylor	2.45	53
September 9	L. L. Richards	2.21	40

Daily gage height, in feet, of Carson River (West Fork) at Woodfords, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.00	3.70	4.40	3.10	3.90	4.60	4.20	2.50	2.30	2.20	2.40	2.50
2	2.90	3.90	4.60	3.20	3.90	4.50	3.90	2.40	2.30	2.20	2.40	2.50
3	2.90	3.80	4.20	3.40	3.80	4.50	3.80	2.40	2.20	2.20	2.40	2.50
4	2.90	3.90	3.90	3.40	3.70	4.40	3.80	2.40	2.20	2.20	2.40	2.50
5	2.90	4.00	3.60	3.50	3.70	4.40	3.80	2.40	2.20	2.20	2.30	2.50
6	2.80	4.00	3.60	3.80	3.70	4.40	3.60	2.40	2.20	2.20	2.30	2.50
7	2.90	4.00	3.50	3.90	3.60	4.40	3.60	2.40	2.20	2.20	2.40	2.50
8	3.00	3.50	3.50	3.90	3.60	4.60	3.50	2.40	2.20	2.20	2.30	2.50
9	3.00	3.90	3.60	3.80	3.70	4.50	3.40	2.60	2.20	2.20	2.40	2.50
10	3.00	3.90	3.60	3.80	3.80	4.50	3.40	2.40	2.20	2.20	2.40	2.50
11	2.90	3.80	3.60	3.90	4.00	4.40	3.40	2.30	2.20	2.20	2.50	2.50
12	2.90	3.80	3.40	3.90	4.00	4.40	3.20	2.30	2.20	2.20	2.50	2.70
13	2.80	3.90	3.50	3.90	4.00	4.40	3.20	2.30	2.30	2.30	2.50	2.60
14	2.90	3.80	3.60	3.90	4.10	4.40	3.00	2.40	2.30	2.20	2.60	2.50
15	2.90	3.80	3.40	3.80	4.20	4.00	3.00	2.40	2.30	2.30	2.50	2.50
16	2.90	3.90	3.30	3.80	4.40	4.20	2.90	2.30	2.30	2.30	2.40	2.60
17	3.00	4.00	3.20	3.60	3.80	4.10	2.90	2.30	2.30	2.20	2.40	2.60
18	2.90	3.90	3.00	3.50	3.80	4.10	2.90	2.30	2.30	2.20	2.40	2.60
19	2.90	3.80	2.80	3.40	3.80	4.10	2.80	2.30	2.30	2.30	2.40	2.60
20	3.00	3.90	2.70	3.30	3.90	4.10	2.90	2.30	2.30	2.30	2.40	2.60
21	3.20	3.80	2.70	3.30	4.20	4.10	2.90	2.30	2.20	2.30	2.50	2.70
22	3.10	3.90	2.80	3.30	4.30	4.20	2.80	2.30	2.20	2.30	2.50	2.70
23	3.20	3.90	2.60	3.40	4.40	4.20	2.90	2.30	2.20	2.30	2.50	2.80
24	3.20	4.00	2.60	3.40	4.60	4.30	2.90	2.40	2.20	2.30	2.50	2.80
25	3.30	4.20	2.60	3.30	4.60	4.20	2.80	2.50	2.20	2.40	2.50	2.80
26	3.20	4.20	2.60	3.40	4.80	4.10	2.70	2.40	2.20	2.30	2.60	2.80
27	3.40	4.30	2.60	3.30	4.80	4.10	2.70	2.30	2.20	2.20	2.60	2.80
28	3.50	4.30	2.60	3.50	4.80	4.20	2.60	2.30	2.20	2.30	2.50	2.80
29	3.60	.....	2.60	3.50	4.70	4.30	2.60	2.30	2.20	2.40	2.50	2.60
30	3.60	.....	2.60	3.60	4.70	4.30	2.60	2.30	2.20	2.40	2.50	2.60
31	3.70	.....	2.80	.....	4.70	.....	2.60	2.30	.....	2.40	.....	2.50

ting table for Carson River (West Fork) at Woodfords, Cal., for 1902.

ge ht.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
et.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
.4	2	2.4	42	3.4	147	4.4	342
.6	6	2.6	57	3.6	178	4.6	393
.8	12	2.8	75	3.8	213	4.8	448
.0	20	3.0	96	4.0	252	5.0	508
.2	30	3.2	120	4.2	295		

ated monthly discharge of Carson River (West Fork) at Woodfords, Cal.

[Drainage area, 70 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
ary	195	75	107	6,579	1.53	1.76
ary	318	162	238	13,218	3.40	3.54
1	393	57	138	8,485	1.97	2.27
	232	108	175	10,413	2.50	2.79
	448	178	287	17,647	4.10	4.73
	393	252	319	18,982	4.56	5.09
	295	57	121	7,440	1.73	1.99
st	57	36	40	2,460	.57	.66
nber	36	30	32	1,904	.46	.51
er	42	30	34	2,091	.49	.56
nber	57	36	46	2,737	.66	.74
nber	75	49	58	3,566	.83	.96
The year	448	30	133	95,522	1.90	25.60

TRUCKEE RIVER AT TAHOE, CAL.

uckee River, the natural outlet of Lake Tahoe, leaves the lake at city of Tahoe. About 500 feet from the lake there is a timber across the river, which has been maintained for more than ty years, for the purpose of controlling the discharge from the

June 17, 1900, a gage was placed in the stream for the purpose cording the height of the water in the river. The gage is a vertimber driven into the stream bed at the left bank about 300 feet w the dam, and is spiked to the root of a tree growing on the . The bench mark is cut in the side of the tree and is 4 feet e *gage datum. The* measurements are made from a cable

and suspended car about one-fourth mile below the gage, which was placed as near the city of Tahoe as possible for the convenience of the observer. At the point of measurement the right bank is low and is subject to overflow at very high stages of the stream. The left bank is rather high. The channel is nearly straight for a short distance below the station, and the bed of the river, which is of gravel and coarse sand, is smooth and stable. The purpose of the station is to ascertain the actual overflow from Lake Tahoe with a view to determining its real value as a storage reservoir.

The following measurement was made in 1902 by E. C. Murphy:

October 22: Gage height, 1.67 feet; discharge, 320 second-feet.

Daily gage height, in feet, of Truckee River at Tahoe, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	0.80	0.95	0.40	0.40	0.35	0.80	0.80	1.90	2.00	1.75	1.80	1.93
2	.80	.35	.35	.40	.35	.80	.80	1.90	2.00	1.75	1.80	1.90
3	.90	.35	.35	.40	.35	.80	.80	1.90	2.00	1.75	1.87	1.90
4	.90	.35	.35	.40	.35	.80	.80	1.90	2.00	1.75	1.87	1.90
5	.90	.35	.35	.40	.90	.80	.80	1.90	2.00	1.75	1.87	1.90
6	.90	.35	.35	.40	.90	.80	.80	1.90	2.00	1.70	1.87	1.90
7	.90	.35	.35	.40	.90	.80	.95	1.90	1.80	1.70	1.87	1.80
8	.90	.35	.35	.35	.90	.80	.95	1.90	1.80	1.75	1.87	1.80
9	.90	.90	.35	.35	.90	.80	.95	1.90	1.80	1.80	1.70	1.80
10	.90	.90	.35	.35	.90	.80	.95	1.90	1.80	1.80	1.70	1.75
11	.90	.90	.35	.35	.85	.80	.95	1.90	1.80	1.80	1.70	1.75
12	.90	.00	.35	.35	.85	.80	.95	1.90	1.80	1.80	1.70	1.75
13	.90	.00	.35	.35	.80	.80	.95	1.90	1.80	1.80	1.70	1.75
14	.90	.95	.35	.35	.80	.80	1.20	2.10	1.80	1.80	1.70	1.75
15	.90	.95	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.70	1.75
16	1.00	.95	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.70	1.75
17	1.00	.95	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.70	1.70
18	1.00	.90	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.70	1.70
19	1.00	.90	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.92	1.70
20	1.00	.40	.35	.35	.80	.70	1.20	2.10	1.80	1.75	1.92	1.70
21	1.00	.40	.35	.35	.80	.75	1.20	2.10	1.75	1.70	1.92	1.70
22	1.00	.40	.35	.35	.80	.80	1.20	2.10	1.80	1.70	1.92	1.70
23	1.00	.40	.35	.35	.80	.80	1.90	2.10	1.80	1.70	1.92	1.70
24	1.00	.40	.35	.35	.80	.80	1.90	2.10	1.80	1.70	1.92	1.70
25	.95	.40	.35	.35	.80	.80	1.90	2.00	1.80	1.70	1.92	1.70
26	.95	.40	.35	.35	.80	.80	1.90	2.00	1.75	1.70	1.92	1.70
27	.95	.40	.30	.35	.80	.80	1.90	2.00	1.75	1.70	1.92	1.70
28	.95	.40	.80	.35	.80	.80	1.60	2.00	1.75	1.80	1.92	1.65
29	1.05	.....	.80	.35	.80	.80	1.90	2.00	1.75	1.80	1.92	1.65
30	.95	.....	.80	.35	.80	.80	1.90	2.00	1.75	1.80	1.93	1.65
31	1.05	.....	.40	.....	.80	.....	1.90	2.00	.....	1.80	.....	1.65

Rating table for Truckee River at Tahoe, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.0	25	0.7	85	1.4	225	2.1	445
.1	30	.8	100	1.5	251	2.2	486
.2	36	.9	117	1.6	279	2.3	531
.3	43	1.0	136	1.7	308	2.4	580
.4	51	1.1	156	1.8	339		
.5	61	1.2	178	1.9	372		
.6	72	1.3	201	2.0	407		

Estimated monthly discharge of Truckee River at Tahoe, Cal.

[Drainage area, 519 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	146	100	125	7,686	0.24	0.28
ebruary	126	25	73	4,054	.14	.15
arch	100	43	52	3,197	.10	.12
pril	51	47	48	2,856	.10	.11
ay	117	47	97	5,964	.19	.22
ne	100	40	95	5,653	.18	.20
ly	372	100	204	12,543	.39	.45
gust	445	372	406	24,964	.78	.90
ptember	407	324	350	20,826	.67	.75
tober	339	308	324	19,922	.62	.71
vember	407	308	346	20,588	.67	.75
cember	407	293	326	20,045	.63	.73
The year	445	25	204	148,298	.39	5.37

TRUCKEE RIVER AT VISTA, NEV.

The station at Vista, Nev., was established August 18, 1899, by H. Taylor, and is located 7 miles east of Reno. On November 12, 02, a new gage was installed by E. C. Murphy. It consists of a ver- al 4 by 4 inch timber spiked to a willow tree. It is on the left bank the river, 150 feet above the new railroad bridge. The zeros of the l and new gages coincide. The bench mark consists of two spikes 'ven into the root of the willow tree to which the gage is attached.

The elevation of the bench mark is 6.98 feet above the zero of gage. The cable was moved to a point about a quarter of a mile be the old station. The left bank is low and subject to overflow at extr high water. The bed is rocky and not subject to change.

The following discharge measurements were made during 19 C. V. Taylor:

April 9: Gage height, 5.04 feet; discharge, 1,678 second-feet.
May 9: Gage height, 5.70 feet; discharge, 2,319 second-feet.

Daily gage height, in feet, of Truckee River at Vista, Nev.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov
1902.											
1	2.60	2.60	3.40	4.00	4.20	4.60	2.60	2.60	2.80	2.65	3.1
2	2.55	2.70	3.30	4.00	4.00	4.80	2.70	2.50	2.90	2.60	3.1
3	2.50	2.70	3.20	4.45	3.80	4.00	2.60	2.40	3.00	2.70	3.1
4	2.65	2.65	3.20	4.00	3.90	4.00	2.60	2.40	3.10	2.65	3.2
5	2.75	2.65	3.20	4.80	3.90	4.00	2.70	2.40	2.80	2.60	3.1
6	2.75	2.65	3.30	7.00	4.50	4.00	2.60	2.30	2.90	2.60	3.1
7	2.80	2.60	3.30	7.00	5.20	4.20	2.60	2.20	3.10	2.60	3.0
8	2.80	2.60	3.50	5.60	5.70	4.50	2.50	2.20	2.80	2.70	3.0
9	2.75	2.65	3.10	5.00	5.70	4.70	2.50	2.10	2.90	2.70	3.30
10	2.75	2.60	3.05	5.00	5.40	4.80	2.50	2.10	2.70	2.70	3.40
11	2.70	2.60	2.95	5.40	5.60	4.90	2.40	2.10	2.60	2.70	3.50
12	2.60	2.65	3.00	5.00	5.70	4.50	2.40	2.20	2.60	2.80	3.60
13	2.60	2.70	2.90	5.72	5.50	4.40	2.20	2.10	2.70	2.70	3.60
14	2.60	2.90	2.85	5.75	5.30	4.40	2.20	2.40	2.80	2.80	3.70
15	2.60	4.00	2.90	5.71	5.00	4.00	2.30	2.60	2.70	2.80	4.00
16	2.60	4.00	2.80	5.77	4.70	3.90	(a)	2.80	2.60	2.80	3.90
17	2.60	3.60	2.80	5.77	4.80	3.80	.....	2.50	2.70	2.70	3.80
18	2.65	3.20	2.85	5.76	4.70	3.70	.....	2.60	2.60	2.90	3.80
19	2.70	3.25	2.90	5.79	4.60	3.70	.....	2.50	2.60	2.90	3.70
20	2.60	3.25	2.90	5.77	4.20	3.60	.....	2.60	2.70	3.10	3.60
21	2.60	3.20	2.85	5.77	4.10	3.70	.....	2.60	2.70	2.90	3.60
22	2.60	3.15	2.80	4.78	4.00	3.40	.....	2.60	2.70	3.00	3.40
23	2.60	3.00	2.80	4.79	3.90	3.40	.....	2.60	2.70	3.00	3.40
24	2.55	3.30	2.85	4.75	4.00	3.40	.....	2.60	2.70	3.10	3.40
25	2.65	3.50	2.80	4.72	4.50	3.40	.....	2.50	2.70	3.10	3.40
26	2.60	3.50	2.90	4.71	4.80	3.40	.....	2.50	2.70	2.90	3.30
27	2.70	3.60	2.90	4.10	5.20	3.30	2.30	2.60	2.70	3.10	3.30
28	2.60	3.55	2.90	4.10	5.60	3.20	2.60	2.70	2.70	3.00	3.30
29	2.60	.....	3.00	4.20	5.40	2.80	2.60	2.70	2.70	3.00	3.20
30	2.60	.....	3.40	4.30	5.20	2.60	2.70	2.80	2.60	3.10	(a)
31	2.60	.....	3.70	.....	5.00	.....	2.60	2.80	.....	3.00	.....

[a] No record July 16 to 26 and November 30 to December 31.

Rating table for Truckee River at Vista, Nev., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.0	110	3.4	773	4.8	1,601	6.2	2,780
2.2	185	3.6	882	5.0	1,733	6.4	3,079
2.4	274	3.8	995	5.2	1,871	6.6	3,438
2.6	370	4.0	1,110	5.4	2,015	6.8	3,857
2.8	467	4.2	1,227	5.6	2,168	7.0	4,336
3.0	566	4.4	1,348	5.8	2,338		
3.2	668	4.6	1,473	6.0	2,537		

Estimated monthly discharge of Truckee River at Vista, Nev.

[Drainage area, 1,519 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	467	322	389	23,919	0.256	0.30
February	1,110	370	598	33,211	.393	.41
March	938	467	589	36,216	.388	.45
April	4,336	1,110	1,922	114,367	1.265	1.42
May	2,250	995	1,610	98,995	1.060	1.22
June	1,666	370	1,056	62,836	.695	.78
July	418	185	292	17,954	.192	.22
August	467	146	311	19,123	.205	.24
September	617	370	443	26,360	.292	.33
October	617	370	485	29,821	.319	.37
November 1 to 29	1,110	566	782	44,981	.515	.56

TRUCKEE RIVER AT NEVADA-CALIFORNIA STATE LINE, NEAR MYSTIC, CAL.

The gaging station on this river was established by L. H. Taylor September 7, 1899, at the State line, 17 miles west of Reno, Nev. The old gage was vertical, driven into the bed of the river, and wired to a granite bowlder. A new gage was established by E. C. Murphy November 11, 1902. It is a 4 by 4 inch timber in two parts and is located on the right bank 400 feet below the old gage. The lower section of the gage is inclined; the upper part is vertical. The zeros of the old and new gages coincide. The bench mark consists of two spikes driven into the root of the cottonwood tree to which the ver-

tical portion of the gage is attached. The elevation of the bench mark is 5.99 feet above the zero of the gage.

The following discharge measurements were made during 1902 by C. V. Taylor:

April 10: Gage height, 3.60 feet; discharge, 1,492 second-feet.
May 10: Gage height, 4.50 feet; discharge, 2,384 second-feet.

Daily gage height, in feet, of Truckee River at Nevada-California State line near Mystic, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.50	1.40	2.10	2.20	3.40	3.70	2.40	2.10	2.20	1.90	1.90	1.90
2	1.90	1.60	2.10	2.10	3.30	3.70	2.20	2.10	2.20	2.00	1.80	2.00
3	1.80	1.60	1.90	2.20	3.20	3.50	2.20	2.10	2.20	1.90	1.90	2.00
4	1.60	1.60	2.00	2.20	3.20	3.50	3.00	2.10	2.20	1.90	1.80	2.10
5	1.50	1.70	2.10	2.50	3.30	3.40	2.10	2.00	2.20	1.90	1.90	2.10
6	1.60	1.60	2.40	3.20	3.90	3.50	2.10	2.00	2.10	1.80	1.90	2.10
7	1.50	1.70	1.90	5.00	4.40	3.90	2.10	2.00	2.20	1.90	1.80	2.20
8	1.50	1.80	1.90	4.00	4.80	3.90	2.10	2.00	2.10	2.10	1.90	2.10
9	1.60	1.80	1.80	4.10	4.80	4.00	1.70	2.00	2.00	1.90	1.90	2.20
10	1.50	2.10	1.50	3.70	4.70	4.10	2.00	1.80	2.00	1.90	2.20	2.40
11	1.40	2.10	1.60	3.40	4.80	4.00	2.10	2.10	2.00	2.00	2.50	2.20
12	1.50	1.80	1.60	3.50	4.70	3.90	2.00	2.10	2.00	2.00	1.90	2.30
13	1.60	1.50	2.00	3.60	4.50	3.90	1.90	2.00	2.20	2.00	1.90	2.00
14	1.70	1.80	1.70	4.10	4.00	3.90	1.90	2.10	2.10	2.00	1.90	1.80
15	1.50	2.40	1.60	4.30	4.00	3.50	2.00	2.20	2.00	1.90	2.10	1.80
16	1.60	2.50	1.50	4.20	4.00	3.30	2.00	2.20	1.90	1.90	1.90	2.00
17	1.60	3.20	1.60	4.50	4.10	3.30	1.90	2.10	1.90	1.90	2.10	1.80
18	1.80	2.50	1.70	5.00	4.00	3.20	1.90	2.10	2.00	1.90	1.90	1.90
19	1.50	2.30	1.80	5.40	3.80	3.20	1.90	2.10	2.00	1.90	1.80	1.80
20	1.50	2.30	1.80	5.00	3.50	3.20	1.90	2.10	1.90	1.90	1.90	2.00
21	1.50	2.20	1.90	4.30	3.40	3.20	1.80	2.10	2.00	1.90	2.10	2.10
22	1.50	2.00	1.70	3.80	3.30	3.20	1.90	2.00	2.00	1.90	1.70	2.10
23	1.50	2.00	1.70	3.80	3.40	3.00	1.80	2.10	2.00	1.90	1.70	2.10
24	1.70	2.90	1.50	3.40	3.50	3.10	2.10	2.10	2.00	2.20	1.50	2.10
25	1.60	2.40	1.70	3.40	4.00	3.10	2.20	2.10	1.90	2.20	1.70	2.10
26	1.40	2.00	1.70	3.30	4.20	2.80	2.20	2.10	1.90	2.20	1.70	1.90
27	1.70	2.00	1.70	3.20	4.60	2.80	2.20	2.20	1.90	2.10	1.60	1.90
28	1.80	2.00	2.00	3.20	4.30	2.60	2.20	2.20	2.00	2.10	1.60	1.90
29	1.80	.....	2.00	3.40	4.70	2.50	1.90	2.20	2.00	2.00	1.80	1.90
30	1.70	.....	2.00	3.50	4.40	2.50	2.10	2.20	2.00	1.90	1.80	2.10
31	1.70	.....	2.10	.....	4.20	.....	2.20	2.20	.....	1.90	.....	2.10

Rating table for Truckee River at Mystic, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.4	268	2.6	795	3.8	1,683	5.0	3,002
1.6	319	2.8	924	4.0	1,870	5.2	3,283
1.8	383	3.0	1,055	4.2	2,069	5.4	3,596
2.0	463	3.2	1,194	4.4	2,280	5.6	3,953
2.2	559	3.4	1,345	4.6	2,505	5.8	4,370
2.4	671	3.6	1,508	4.8	2,745		

Estimated monthly discharge of Truckee River at Nevada-California State line near Mystic, Cal.

[Drainage area, 955 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	421	268	322	19,799	0.337	0.39
February	1,194	268	506	28,102	.530	.55
March	671	292	402	24,718	.421	.49
April	3,596	509	1,656	98,539	1.734	1.93
May	2,745	1,194	1,927	118,487	2.018	2.33
June	1,968	732	1,358	80,807	1.422	1.59
July	1,055	349	501	30,805	.525	.61
August	559	383	506	31,113	.530	.61
September	559	421	482	28,681	.505	.56
October	559	383	450	27,669	.471	.54
November	732	292	416	24,754	.436	.49
December	671	383	482	29,637	.505	.58
The year	3,596	268	751	543,111	.786	10.67

INDEPENDENCE CREEK BELOW INDEPENDENCE LAKE, NEAR OVERTON, CAL.

This station was established October 24, 1902, by E. C. Murphy. It is located about one-eighth of a mile below the dam at the end of Independence Lake, California. The gage is a vertical staff graduated to feet and tenths and is located about 200 feet upstream from the cable and car from which the measurements are made. The gage is read twice daily by James McNutt. The channel is straight both above and below the station. The banks are low, but not subject to overflow. The bed of the stream is permanent, being composed of gravel and clay. The bench mark is three nails driven in the root of a pine tree 55 feet northwest of the gage. Its elevation is 5.82 feet above the zero of the gage.

The following discharge measurement was made by E. C. Murphy in 1902:

October 24: Gage height, 1.23 feet; discharge, 0.27 second-foot.

Daily gage height, in feet, of Independence Creek below Independence Lake, near Overton, Cal.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	1.33	2.20	12	.....	1.93	1.60	23	.....	1.93	1.60
2	.....	1.33	2.20	13	.....	1.73	1.60	24	1.23	1.93	1.55
3	.....	1.33	2.00	14	.....	(a)	1.60	25	1.23	1.93	1.55
4	.....	1.23	1.95	15	.....	(a)	1.50	26	1.23	1.93	1.50
5	.....	1.23	1.90	16	.....	1.93	1.50	27	1.13	1.93	1.50
6	.....	1.13	1.90	17	.....	1.93	1.50	28	1.23	1.93	1.75
7	.....	1.23	1.80	18	.....	1.93	1.50	29	1.23	1.93	1.85
8	.....	1.33	1.80	19	.....	1.93	1.50	30	1.23	1.90	1.90
9	.....	1.18	1.80	20	.....	1.93	1.50	31	1.33	.....	1.90
10	.....	1.93	1.60	21	.....	1.93	1.50				
11	.....	1.93	1.60	22	.....	1.93	1.60				

a No record.

PROSSER CREEK NEAR BOCA, CAL.

This station was established October 23, 1902, by E. C. Murphy. It is located about 500 feet below the dam of the Prosser Creek Ice Company. It is about one-eighth of a mile above the mouth of the creek, at the footbridge between two ice houses. The gage is a vertical staff graduated to feet and tenths and located about 10 feet below the bridge. It is read twice daily by C. Lindsley. The channel is straight both above and below the station. The banks are high. The bed of the stream is permanent and is composed of sandy gravel and stone. The bench mark is a spike driven into the timber to which the gage is fastened. Its elevation is 6.0 feet above the zero of the gage.

The following discharge measurement was made in 1902 by E. C. Murphy:

October 23: Gage height, 0.85 foot; discharge, 21 second-feet.

Daily gage height, in feet, of Prosser Creek near Boca, Cal.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	0.75	0.80	12	.....	0.80	0.65	23	0.85	0.85	0.45
2	.....	.80	.80	13	.....	.85	.70	24	.95	.80	.35
3	.....	.75	.45	14	.....	.85	.65	25	.85	.80	.45
4	.....	.80	.65	15	.....	.85	.60	26	.85	.80	.35
5	.....	.80	.85	16	.....	.80	.55	27	.85	.80	.55
6	.....	.75	1.05	17	.....	.85	.65	28	.90	.85	.35
7	.....	.80	.95	18	.....	.85	.85	29	.85	.80	.45
8	.....	.70	1.00	19	.....	.80	.95	30	.85	.75	.40
9	.....	.70	1.10	20	.....	.80	.75	31	.80	.....	.45
10	.....	1.05	1.30	21	.....	.85	.75				
11	.....	1.00	.65	22	.....	.80	.55				

DONNER CREEK NEAR TRUCKEE, CAL.

This station was established October 23, 1902, by E. C. Murphy. It is located about 1½ miles west of Truckee, Cal., near the dam of the Donner Creek Ice Company. The gage is a vertical staff graduated to feet and tenths, located about 50 feet upstream from the cable from which measurements are taken. The gage is read twice daily by F. R. Williams. The channel is straight both above and below the station. The banks of the stream are high. The bed of the stream is permanent, being composed of gravel. The bench mark consists of four nails driven in the root of a pine tree 35 feet north of the gage. The elevation is 6.3 feet above the zero of the gage.

The following discharge measurement was made in 1902 by E. C. Murphy:

October 23: Gage height, 1.80 feet; discharge, 3.2 second-feet.

Daily gage height, in feet, of Donner Creek near Truckee, Cal.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	1.60	1.80	12	.....	1.85	1.95	23	1.80	1.90	1.80
2	.....	1.60	1.80	13	.....	1.85	1.80	24	1.82	1.90	1.85
3	.....	1.60	1.90	14	.....	2.20	1.90	25	1.72	1.90	1.90
4	.....	1.60	1.90	15	.....	1.85	1.90	26	1.60	1.90	1.80
5	.....	1.60	1.90	16	.....	2.00	1.90	27	1.60	1.90	1.80
6	.....	1.60	2.00	17	.....	1.90	1.95	28	1.60	1.90	1.75
7	.....	1.60	1.90	18	.....	2.20	1.90	29	1.65	1.90	1.85
8	.....	1.60	1.90	19	.....	1.90	1.80	30	1.70	1.80	2.25
9	.....	1.60	2.00	20	.....	1.80	1.80	31	1.60	.....	2.35
10	.....	2.05	2.00	21	.....	1.90	1.80				
11	.....	2.05	2.00	22	.....	1.90	1.80				

SUSAN RIVER NEAR SUSANVILLE, CAL.

The gaging station is about three-fourths of a mile southwest of the town, at the electric-light plant. It was established June 3, 1900, by L H. Taylor, a temporary gage being placed at the right bank of the river. The station is designed to be equipped with a cable and suspended car from which to make measurements of the discharge. The channel is straight for a distance above and below the station and the banks are high. The stream bed is of gravel and cobbles and is rather stable. The observer is James Branham.

A short distance above the station a small irrigating ditch, known as the Masten ditch, is taken out on the right bank of the stream. Near its head is a flume in which a gage has been placed and measurements are made.

Daily gage height, in feet, of Susan River near Susanville, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.40	2.40	3.80	3.80	4.42	4.02	2.80	1.90	1.75	1.90	2.10	2.20
2	2.40	2.45	3.70	3.75	4.40	3.92	2.98	1.90	1.75	1.90	2.10	2.20
3	2.40	2.50	3.70	3.80	4.32	3.85	2.88	1.85	1.75	1.90	2.10	2.20
4	2.40	2.55	3.65	3.95	4.30	3.75	2.80	1.85	1.75	1.90	2.10	2.22
5	2.40	2.60	3.60	4.15	4.30	3.65	2.80	1.85	1.75	2.20	2.15	2.30
6	2.40	2.65	3.40	4.32	4.45	3.55	2.75	1.85	1.70	2.20	2.15	2.35
7	2.40	2.70	3.40	5.80	4.65	3.52	2.70	1.85	1.70	2.20	2.20	2.45
8	2.40	2.80	3.35	4.95	4.78	3.48	2.50	1.85	1.70	2.20	2.20	2.55
9	2.40	3.30	3.30	4.68	4.75	3.42	2.38	1.80	1.70	2.20	2.20	2.55
10	2.40	3.50	3.35	4.58	4.75	3.40	2.35	1.80	1.70	2.20	2.65	3.60
11	2.40	3.60	3.35	4.50	4.70	3.62	2.32	1.80	1.70	2.20	2.40	3.50
12	2.40	3.50	3.40	4.50	4.65	3.30	2.30	1.80	1.70	1.95	2.30	3.10
13	2.40	3.20	3.45	4.65	4.60	3.48	2.30	1.80	1.70	1.95	2.28	3.00
14	2.40	3.10	3.55	4.72	4.60	3.65	2.30	1.80	1.75	1.95	2.22	2.85
15	2.40	4.10	3.55	4.90	4.55	3.62	2.25	1.80	1.75	1.95	2.20	2.55
16	2.40	3.90	3.55	5.08	4.48	3.52	2.20	1.85	1.75	1.95	2.28	2.50
17	2.40	4.40	3.85	5.10	4.40	3.40	2.20	1.90	1.75	1.95	2.32	2.40
18	2.40	4.20	3.60	5.25	4.32	3.32	1.95	1.90	1.75	1.95	2.42	2.40
19	2.40	4.10	3.75	5.60	4.32	3.28	1.95	1.90	1.75	2.00	2.40	2.30
20	2.40	3.90	3.75	5.50	4.20	3.22	1.95	1.90	1.75	2.00	2.40	2.30
21	2.40	4.10	3.70	5.25	4.08	3.20	1.90	1.85	1.80	2.00	2.35	2.40
22	2.40	4.00	3.60	5.05	3.98	3.12	1.90	1.85	1.80	2.10	2.33	2.40
23	2.40	3.90	3.60	4.85	3.92	3.07	1.90	1.85	1.85	2.15	2.30	2.45
24	2.40	4.20	3.50	4.85	3.90	3.00	1.90	1.85	1.85	2.15	2.30	2.50
25	2.40	4.10	3.35	4.65	3.90	2.95	1.90	1.80	1.85	2.20	2.25	2.50
26	2.40	3.90	3.30	4.55	3.92	2.90	1.90	1.80	1.90	2.20	2.22	5.05
27	2.40	4.10	3.35	4.50	4.05	2.90	1.90	1.80	1.90	2.20	2.20	4.75
28	2.40	3.90	3.45	4.42	4.02	2.82	1.90	1.75	1.90	2.20	2.20	4.60
29	2.40	.....	3.50	4.45	4.05	2.80	1.90	1.75	1.90	2.15	2.20	4.45
30	2.40	.....	3.50	4.50	4.05	2.80	1.90	1.75	1.90	2.15	2.20	4.20
31	2.40	.....	3.65	.....	4.05	.....	1.90	1.75	.....	2.10	.....	3.95

Miscellaneous measurements in Interior Basin.

HUMBOLDT RIVER BASIN.

Date.	Hydrographer.	Stream.	Locality.	Discharge.
1902.				*Sec.-feet.*
Apr. 22	C. V. Taylor	Humboldt River	Below Pitt dam, Nev	151.0
22	do	Irish American ditch	Near head-gates, Nev	34.7
July 23	D. W. Hays	do	do	28.3
Apr. 22	C. V. Taylor	Southwest ditch	Wagon bridge south of railroad, Nev.	30.3
July 22	D. W. Hays	do	At Railroad bridge, Nev	24.7
Apr. 23	C. V. Taylor	South Riverside ditch	At head-gates, Nev	5.4
23	do	Rodgers ditch	Flume across river	48.4
July 22	D. W. Hays	do	do	41.7
Apr. 23	C. V. Taylor	Union canal	Box near head	23 0
July 23	D. W. Hays	do	do	28.3

Miscellaneous measurements in Interior Basin—Continued.

WALKER RIVER BASIN.

Date.	Hydrographer.	Stream.	Locality.	Discharge.
1902.		*West Fork and tributaries.*		*Sec.-feet.*
Aug. 8	D. W. Hays	West Walker River	County bridge, Cal	222.0
July 26	L. H. Taylor	do	Hoys Bridge, Nev.	225.0
Aug. 7	D. W. Hays	do	do	72.0
Sept. 23	do	do	do	32.0
Oct. 4	do	do	do	44.0
July 24	L. H. Taylor	do	Lower end Smiths Valley, Nev.	180.0
Sept. 22	D. W. Hays	do	do	21.0
July 23	L. H. Taylor	do	Wilsons Ford, head of Mason Valley, Nev.	113.0
Sept. 10	D. W. Hays	Tunnel ditch	From West Walker, Mason Valley, Nev.	7.4
		East Walker and tributaries.		
Aug. 21	D. W. Hays	Robinson Creek	Below Twin Lakes, Cal	75.7
Oct. 6	do	do	do	24.0
Aug. 21	do	Buckeye Creek	Above all diversion, Cal	43.2
Oct. 4	do	do	do	20.0
7	do	Somers Creek	do	4.2
7	do	Green Creek	Above all diversion above Standard dam.	7.1
7	do	Dogtown Creek	Above all diversion, Cal	7.1
5	do	Swanger Creek	At bridge below Huntoon ranch, Cal.	5.7
July 23	L. H. Taylor	East Walker River	10 miles below Bridgeport, Cal.	196.0
Aug. 27	D. W. Hays	do	5 miles below Bridgeport, Cal.	80.0
Oct. 6	do	do	do	58.0
Aug. 28	do	Sweetwater Creek	East Walker River toll-road crossing, Nev.	.65
31	do	East Walker River	Webster's ranch, Nev	66.0
Sept. 6	do	do	do	42.0
July 23	L. H. Taylor	do	Strosnider's ranch, Nev	106.0
Sept. 11	D. W. Hays	Walker River	Nordyke, Nev	14.0
		Ditches from Walker River.		
July 23	L. H. Taylor	Meritt ditch	Mason Valley, Nev	11.9
23	do	Mason Slough	Headgates, Mason Valley, Nev.	63.8
23	do	Slough	At Mason's house, Nev	7.3

CARSON RIVER BASIN.

1902.		*Tributaries of East Fork.*		
Aug. 6	C. V. Taylor	Indian Creek	At head Cohn and Harvey ditch, Cal.	0.72
6	do	Hawkins Creek	¼ mile above Hawkins's house, Cal.	1.18
Sept. 9	L. L. Richard	do	do	1.10
Aug. 6	C. V. Taylor	Petersons Creek	Near old sawmill, Cal	1.27
Sept. 9	L. L. Richard	do	Above Cohn's meadow	.41
Aug. 5	C. V. Taylor	Long Valley Creek	Diamond Valley, Cal	4.12
5	do	do	Above Springmeyer's ranch, Nev.	2.48
5	do	do	Dam site of Long Valley reservoir site, Nev.	.51

Miscellaneous measurements in Interior Basin—Continued.

CARSON RIVER BASIN—Continued.

Date.	Hydrographer.	Stream.	Locality.	D cha
1902.		*Tributaries of West Fork.*		Sec.
Aug. 6	C. V. Taylor	Bruns Creek	Mouth of canyon, Cal	
Sept. 9	L. L. Richard	do	do	
Aug. 4	C. V. Taylor	Fairview Creek	Mouth of canyon, Nev	
Sept. 8	L. L. Richard	do	do	
Aug. 4	C. V. Taylor	Spring	¼ mile north of Heitman's house, Nev.	
4	do	do	Near Heitman's house, Nev	
Sept. 8	L. L. Richard	do	do	
Aug. 4	C. V. Taylor	do	South of Heitman's house, Nev.	
Sept. 8	L. L. Richard	do	do	
Aug. 4	C. V. Taylor	do	Heitmans, Nev	
Sept. 8	L. L. Richard	do	do	
Aug. 4	C. V. Taylor	S. Sheridan Creek	¼ mile from road, Nev	
Sept. 8	L. L. Richard	do	Mouth of canyon, Nev	
8	do	do	Above old house, Nev	
Aug. 4	C. V. Taylor	Sheridan Creek	¼ mile above Sheridan, Nev	
Sept. 8	L. L. Richard	do	Near old house, Nev	
Aug. 4	C. V. Taylor	Parks Creek	In canyon, Nev	
Sept. 8	L. L. Richard	do	Mouth canyon, Nev	
8	do	Motts Creek	do	
Aug. 4	C. V. Taylor	do	¼ mile above mouth canyon, Nev.	
4	do	Kingsbury Creek	In canyon, Nev	
Sept. 7	L. L. Richard	do	Bridge above old mill, Nev	
Aug. 3	C. V. Taylor	Genoa Creek	Above all diversions, Nev	
Sept. 7	L. L. Richard	do	Mouth of canyon, Nev	
Aug. 3	C. V. Taylor	Dressler Creek	do	
Sept. 7	L. L. Richard	do	do	
Aug. 3	C. V. Taylor	James Canyon Creek	do	
Sept. 11	L. L. Richard	do	Below Genoa road, Nev	
Aug. 3	C. V. Taylor	Jacks Valley Creek	Mouth of canyon, Nev	
Sept. 7	L. L. Richard	do	Above Genoa road, Nev	
Aug. 2	C. V. Taylor	Pedrolis ditch	Pedrolis, Nev	
Sept. 11	L. L. Richard	do	do	
Aug. 2	C. V. Taylor	Clear Creek	do	
Sept. 11	L. L. Richard	do	Above lower ditch, Nev	
Aug. 2	C. V. Taylor	Kings Canyon Creek	Above all diversions, Nev	
7	do	do	Robinsons Box, Nev	
7	do	do	Mouth of canyon, Nev	
Sept. 6	L. L. Richard	do	do	
11	do	do	do	
Aug. 10	C. V. Taylor	do	do	
2	do	Ash Canyon Creek	¼ mile above mouth canyon, Nev.	
Sept. 6	L. L. Richard	do	Mouth canyon, Nev	
11	do	do	do	
Aug. 7	C. V. Taylor	Walsh ditch		
7	do	Muldoon ditch	Head of ditch, Nev	
7	do	Water Co. ditch	do	
6	do	Thorn ditch	do	

SAN FRANCISCO BAY DRAINAGE BASIN.

Sacramento River, rising in northern California and flowing south, and the San Joaquin, rising in the southern sierras and flowing northeast, drain the western slope of the Sierra Nevada, traverse what is often called the Valley of California, and meet near Suisun Bay, finally discharging their waters into the Pacific Ocean through San Francisco Bay.

Sacramento River derives its water supply largely from Mount Shasta and the surrounding high ranges in the extreme northern portion of California. The stream does not have the same regular annual fluctuations that characterize the rivers discharging from the higher Sierra Nevada, in that a large part of its basin is not at an elevation sufficient to cause the winter snows to remain unmelted until the summer months. The greatest floods of this basin usually occur in January and February, when the snow is accompanied or followed by rain.

San Joaquin River is divided into two distinct parts. The valley portion forms the central drainage line of San Joaquin Valley, and during the spring is navigable for a hundred or more miles. The Stanislaus, Tuolumne, and King rivers are the largest affluents of this portion of the stream. Its valley is fertile and almost destitute of timber. The mountainous portion of the stream drains the western slopes of the Sierra Nevada between Yosemite National Park and Mount Goddard, the crest of its divide reaching an elevation on the north, in Mount Lyell, of 13,000 feet, and an elevation of 14,000 feet in Mount Goddard. The resulting steep grades of this river offer exceptional opportunities for water-power developments, and the high elevations of the basin insure a well-sustained summer flow from perpetual snow banks.

The following streams are tributary to either the Sacramento or San Joaquin rivers:

Cache Creek is the outlet of Clear Lake, in Lake County, Cal. Flowing southeasterly, its flood waters find their way into Sacramento River between the mouths of Feather and American rivers. In 1889 Clear Lake was segregated as a reservoir site, as described in the Thirteenth Annual Report, Part III, pages 405–409. During 1900 a hydrographic examination of the entire basin of Cache Creek was made by A. E. Chandler, whose detailed report has been published as Water-Supply Paper No. 45.

Feather River is the second largest tributary of Sacramento River, Pit River being the first. Its basin line follows the crest of the Sierra Nevada for about 130 miles. The rainfall in this basin is large; the mean for nineteen years at Mumfords Hill, Plumas County, is 71.64 inches; the rainfall for the year 1889–90 at this point reached *138.85 inches. The water collected* by the river when rains are gen-

eral sometimes causes tremendous freshets, usually of short duration The river has at such times overtopped its right bank and overflowe the plain lands to the northward of Sutter Buttes. This occurred eve before the great reduction of waterway below the mouth of Yub River. The channel of the river below its junction with the Yub has become the repository of so much mining débris that its bed ha become nearly filled. Its bottom is almost at the heights of its forme banks. Levees have been built to prevent overflowing. There is comparatively small portion of the summer flow of this stream use for irrigation, though the possibilities of irrigation and power develop ment are great.

There are some excellent reservoir sites on the upper tributaries o the North Fork of the Feather. This stream is fed in part by large springs, one of which in Big Meadows was flowing 109 cubic feet per second in September, 1902, and another 64 cubic feet per second.

Stony Creek drains 760 square miles of the eastern slopes of the Coast Range. After reaching the Sacramento Valley it flows north for a number of miles, contrary to the general drainage, and then turns east and enters Sacramento River below Vina, Cal. A large portion of the basin near the heads of the stream is heavily covered with commercial timber. There are a number of good reservoir sites on this stream and its tributaries.

Tuolumne River rises on the western slope of the Sierra Nevada in California and drains the country between Stanislaus River on the north and Merced River on the south. The northern half of Yosemite National Park includes a portion of the drainage basin of this stream. The river is fed largely from small mountain lakes occurring high in the drainage basin, where the snow remains on the mountain slopes throughout the year, thus insuring a large run-off. The stream has a heavy fall, and the opportunities for power development are numerous. There are also a number of reservoir sites in the basin where flood water could be stored for use during the irrigation season. The Tuolumne is an important tributary of the San Joaquin.

Merced River above Merced Falls drains approximately 1,090 square miles of the western slopes of the Sierra Nevada. There are included in the eastern portion of its drainage area a large number of high peaks, the highest, Mount Lyell, reaching an elevation of 13,042 feet Its basin lies south of that of the Tuolumne, the courses of the two streams being nearly parallel.

King River rises on the western slope of the Sierra Nevada, in Fresno County, Cal. The waters coming from the high catchmen basin are probably of greater value for irrigation purposes than those of any other stream in central California, being used for raising grape and deciduous fruits in the neighborhood of Fresno, Selma, and Hanford. The summer flow of the river is now entirely diverted, and during the dry season of the last few years the scarcity of water ha

caused many hardships. In the spring there is a large surplus, due to the melting of snows, which, if stored in suitable reservoirs, would bring larger areas under cultivation. The river has a relatively gentle grade, affording little opportunity for power development.

Tule River drains a portion of the western slope of the Sierra Nevada. Its basin has somewhat less run-off than that of Kaweah River, which joins it on the north, and is much less elevated and snow covered than the King River Basin. The water of this stream is all appropriated during the irrigation season, and a portion is used in irrigating valuable orange lands in the vicinity of Portersville, Cal.

Kern River flows from the southern end of the Sierra Nevada, being formed by two large tributaries, known as the North and South forks. These have a general southerly and parallel course and unite a short distance below the town of Kernville. The run-off from the drainage basin as a whole is notably less than that from the catchment areas to the north. This is probably due to the fact that a portion of the basin is to the east of the high crest, and is sheltered by the mountain mass from the rain-bearing winds. The waters of Kern River are almost completely used for irrigation by the large canals in the southern end of the San Joaquin Valley. The greater part of the land is included in large holdings owned by the Kern County Land Company or by the Miller and Lux estate. The winter waters are in part stored by the Miller and Lux estate in Buena Vista Lake, into which the river naturally discharges. The waters of this lake are controlled by a system of levees, so that they can be used during the following summer to irrigate lands lying to the northwest. This lake is very broad and shallow and there is great loss by evaporation, so that as a matter of economy it would be desirable to hold this water in the upper mountain valleys. This would afford also a large supply for water power.

The fall of Kern River is sufficiently large for the development of a considerable amount of water power.

The following is a list of the stations in the San Francisco Bay drainage basin:

Cache Creek at Lower Lake, Cal.
Feather River at Oroville, Cal.
Stony Creek at Julians ranch, near Fruto, Cal.
Sacramento River at Jellys Ferry and at Iron Canyon, near Red Bluff, Cal.
Tuolumne River and Turlock Canal at Lagrange, Cal.
Merced River above Merced Falls, Cal.
King River at Kingsburg, Cal.
King River at Red Mountain, near Sanger, Cal.
Tule River near Portersville, Cal.
Kern River near Bakersfield, Cal.
San Joaquin River at Herndon, Cal.

CACHE CREEK AT LOWER LAKE, CAL.

On account of the great importance of Clear Lake as a storage reservoir, a gaging station was established at the wagon bridge across Cache Creek, one-half mile north of the town of Lower Lake, January 1, 1901. The observer is Mrs. J. R. Anderson.

Evaporation records have been kept at Lakeport on Clear Lake since February 1, 1901. The evaporation pan is 3 feet square and 1.5 feet deep and is floated on a triangular raft anchored in a cove where it is not exposed to the full force of the wind. Evaporation observations were begun on the land at the same point September, 1901. Capt. D. C. Rumsey is the observer. A table giving the evaporation, by months, from February, 1901, to December 31, 1902, will be found in the following pages.

Discharge measurements of Cache Creek at Lower Lake, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 29	J. R. Anderson	1.6	70
February 13	do	2.5	260
March 3	do	6.5	1,151
March 19	do	7.7	1,866
April 5	do	6.5	1,397
April 24	do	5.9	1,212
May 3	S. G. Bennett	5.2	1,042
May 19	J. R. Anderson	4.5	853
May 31	do	4.0	720
June 14	do	3.6	629
July 12	do	3.1	422
July 26	do	2.8	345
August 9	do	2.7	289
August 22	do	2.5	246
September 6	do	2.3	193
September 20	do	2.2	156
October 4	do	2.1	108
October 20	do	2.0	83
November 4	do	2.1	118
November 19	do	2.8	245
December 19	S. G. Bennett	2.8	300

Daily gage height, in feet, of Cache Creek at Lower Lake, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.6	1.6	5.9	6.5	5.4	4.0	3.3	2.8	2.4	2.1	2.1	2.7
2	1.6	1.6	6.6	6.5	5.3	4.0	3.3	2.7	2.4	2.1	2.1	2.7
3	1.6	1.6	6.5	6.5	5.3	3.9	3.2	2.7	2.4	2.1	2.1	2.7
4	1.6	1.7	6.5	6.5	5.2	3.9	3.2	2.7	2.3	2.1	2.1	2.7
5	1.6	1.7	6.5	6.5	5.1	3.9	3.2	2.7	2.3	2.1	2.0	2.7
6	1.6	1.8	7.2	7.0	5.0	3.8	3.2	2.7	2.3	2.1	2.0	2.7
7	1.6	1.9	7.0	6.9	5.1	3.8	3.2	2.7	2.3	2.1	2.1	2.7
8	1.6	2.0	8.0	6.8	5.1	3.8	3.2	2.7	2.3	2.1	2.2	2.7
9	1.6	2.1	8.0	6.8	5.0	3.8	3.2	2.7	2.3	2.1	3.7	2.7
10	1.6	2.1	8.1	6.8	5.0	3.7	3.1	2.6	2.3	2.1	2.8	2.8
11	1.6	3.2	8.0	6.8	4.9	3.7	3.1	2.6	2.3	2.1	2.8	2.8
12	1.6	2.4	8.0	6.7	4.7	3.7	3.1	2.6	2.3	2.1	2.8	2.8
13	1.6	2.5	8.2	6.6	4.7	3.7	3.1	2.6	2.3	2.1	2.8	2.8
14	1.6	2.6	8.0	6.6	4.8	3.6	3.1	2.6	2.3	2.1	2.8	2.8
15	1.6	2.6	7.9	6.5	4.7	3.6	3.0	2.6	2.2	2.1	2.8	2.8
16	1.6	2.6	7.8	6.5	4.7	3.6	3.0	2.6	2.2	2.	2.8	2.8
17	1.6	2.8	7.8	6.5	4.7	3.6	3.0	2.6	2.2	2.0	2.8	2.8
18	1.5	2.7	7.7	6.5	4.6	3.5	3.0	2.5	2.2	2.	2.8	2.8
19	1.6	2.7	7.7	6.5	4.5	3.5	3.0	2.5	2.2	2.0	2.8	2.8
20	1.5	2.8	7.6	6.3	4.5	3.5	3.0	2.5	2.2	2.0	2.8	2.8
21	1.6	3.3	7.4	6.2	4.4	3.5	3.0	2.5	2.2	2.0	2.8	2.8
22	1.7	3.1	7.4	6.0	4.3	3.5	3.0	2.5	2.2	2.0	2.8	2.8
23	1.6	4.6	7.5	5.9	4.3	3.5	2.9	2.5	2.2	2.1	2.8	2.8
24	1.7	4.4	7.2	5.9	4.2	3.4	2.9	2.5	2.2	2.2	2.7	2.8
25	1.8	6.1	7.2	5.8	4.2	3.4	2.9	2.4	2.2	2.1	2.7	2.8
26	1.7	5.0	7.1	5.8	4.1	3.4	2.8	2.4	2.2	2.1	2.7	2.9
27	1.6	5.5	7.0	5.7	4.1	3.4	2.8	2.4	2.2	2.1	2.7	2.9
28	1.6	5.4	6.8	5.5	4.1	3.3	2.8	2.4	2.2	2.1	2.7	2.9
29	1.6	.....	6.7	5.5	4.1	3.3	2.8	2.4	2.1	2.1	2.7	2.9
30	1.6	.....	6.6	5.4	4.0	3.3	2.8	2.4	2.1	2.1	2.7	2.9
31	1.6	.....	6.5	.....	4.0	.....	2.8	2.4	.....	2.1	.....	2.9

Rating table for Cache Creek at Lower Lake, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.5	40	2.6	250	4.4	790	6.6	1,520
1.6	52	2.7	280	4.6	850	6.8	1,590
1.7	64	2.8	310	4.8	910	7.0	1,660
1.8	78	2.9	340	5.0	970	7.2	1,730
1.9	94	3.0	370	5.2	1,030	7.4	1,800
2.0	110	3.2	430	5.4	1,100	7.6	1,870
2.1	130	3.4	490	5.6	1,170	7.8	1,940
2.2	150	3.6	550	5.8	1,240	8.0	2,010
2.3	175	3.8	610	6.0	1,310	8.2	2,080
2.4	200	4.0	670	6.2	1,380		
2.5	225	4.2	730	6.4	1,450		

Estimated monthly discharge of Cache Creek at Lower Lake, Cal.

[Drainage area, 500 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep inc
1902.						
January	78	40	53	3,259	0.11	
February	1,345	52	381	21,160	.76	
March	2,080	1,275	1,766	108,587	3.53	
April	1,660	1,100	1,427	84,912	2.85	
May	1,100	670	865	53,187	1.73	
June	670	460	556	33,084	1.11	
July	460	310	380	23,365	.76	
August	310	200	243	14,941	.49	
September	200	130	163	9,699	.33	
October	150	110	127	7,809	.25	
November	580	110	263	15,650	.53	
December	340	280	307	18,877	.61	
The year	2,080	40	544	394,530	1.09	

Evaporation record of Clear Lake at Lakeport, Cal.

[D. C. Rumsey, observer.]

	Evaporation in inches.			Evaporation inches.	
	Lake.	Land.		Lake.	La
1901.			1902.		
January (estimated)	0.85	.....	January	0.85	
February	.95	.....	February	.25	
March	2.40	.....	March	1.60	
April	3.05	.....	April	2.60	
May	3.70	.....	May	4.00	
June	3.95	.....	June	4.65	
July	5.15	.....	July	6.65	
August	5.00	.....	August	4.40	
September	3.35	[a] 1.6	September	4.10	
October	2.30	2.45	October	1.95	
November	.85	1.05	November	.45	
December	1.30	.95	December	.40	
	32.85	6.05		31.90	

[a] [illegible] 15 to 29.

FEATHER RIVER AT OROVILLE, CAL.

At Oroville, where Feather River breaks from the foothills on the western slope of the Sierra Nevada into the Sacramento Valley, it has a drainage basin of 3,350 square miles.

The minimum midsummer discharge, as far as known, was in 1900 when the stream was flowing 1,123 second-feet. Observations of daily river stage were begun January 1, 1902, using the rod of the Weather Bureau, which has been in place for a number of years. Readings on this rod have been taken and reported by the Weather Bureau during flood heights when there was danger of overflow on the lower Feather and Sacramento rivers. It was found that there would be minus readings during low stage, and 2 feet have been added to the reading as observed on the rod. The observer is Miss Louise N. Lee.

Discharge measurements of Feather River at Oroville, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 29	S. G. Bennett	1.85	1,960
March 1	do	8.70	15,228
May 7	do	8.75	15,476
September 4	C. A. Miller	.96	1,385
September 10	do	.92	1,390
December 18	S. G. Bennett	3.65	3,298

Daily gage height, in feet, of Feather River at Oroville, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.0	2.0	10.7	6.5	8.6	7.5	2.9	1.4	1.0	0.8	1.2	1.3
2	2.5	2.0	10.5	7.0	7.5	7.0	3.0	1.4	1.0	.8	1.2	1.5
3	2.5	2.0	9.5	8.0	7.2	6.5	3.0	1.4	1.0	.8	1.2	1.8
4	2.0	2.0	8.8	10.0	7.1	6.3	3.0	1.3	.9	.8	1.2	2.0
5	2.0	3.0	8.5	13.0	7.0	6.2	3.0	1.3	.9	.8	1.2	2.6
6	2.0	3.5	8.3	14.0	8.0	6.2	2.9	1.3	.9	.8	1.4	3.0
7	2.0	9.0	8.1	14.0	8.5	6.0	2.7	1.3	.9	.8	2.0	3.8
8	2.0	10.2	8.2	12.3	8.4	6.0	2.5	1.3	.9	.8	3.3	3.8
9	2.0	11.3	8.8	11.2	8.4	5.9	2.5	1.3	.9	.8	3.9	4.2
10	2.0	10.5	8.4	10.6	8.4	5.8	2.4	1.3	.9	.8	8.5	7.8
11	2.0	9.7	8.5	9.2	8.3	5.8	2.4	1.3	.9	.8	5.3	10.0
12	2.0	9.8	7.4	8.9	8.7	5.7	2.3	1.3	.8	.8	3.8	9.0
13	2.0	8.3	6.9	8.7	9.0	5.5	2.2	1.3	.8	.8	3.3	8.5
14	2.0	7.2	6.7	8.6	8.8	5.4	2.2	1.3	.8	.8	3.5	6.3
15	2.0	11.8	6.4	9.9	8.5	4.7	2.1	1.3	.8	.8	3.4	5.2
16	2.0	11.3	6.4	11.5	8.4	5.0	2.0	1.3	.8	.8	3.4	4.5
17	2.0	12.5	6.5	11.0	8.3	4.8	1.9	1.3	.8	.8	4.0	4.0
18	2.0	10.2	6.7	10.5	7.8	4.5	1.9	1.3	.8	.8	5.5	3.5
19	2.0	9.2	6.6	9.5	7.5	4.3	1.8	1.3	.8	.8	6.5	3.3
20	2.0	8.5	6.8	9.4	7.3	4.3	1.8	1.3	.8	.8	5.5	3.3
21	2.0	9.0	6.8	9.8	7.0	4.1	1.7	1.3	.8	1.3	4.5	3.2
22	2.0	9.8	6.6	9.0	6.9	4.1	1.8	1.2	.8	1.8	3.2	3.1
23	2.0	9.5	6.5	9.5	6.8	4.0	1.7	1.2	.8	1.9	3.1	3.1
24	2.0	13.5	6.4	8.2	6.8	4.0	1.7	1.2	.8	3.3	3.1	3.0
25	2.0	13.0	6.3	7.8	7.5	3.8	1.6	1.1	.8	3.4	2.9	3.0
26	2.0	13.8	6.2	7.5	8.0	3.5	1.6	1.1	.8	1.2	2.5	4.0
27	2.0	13.7	6.1	7.4	7.9	3.4	1.6	1.1	.8	1.2	2.1	11.0
28	2.0	12.3	6.0	7.3	7.8	3.3	1.5	1.1	.8	1.2	1.9	8.0
29	2.0	.....	6.0	8.0	7.5	3.2	1.5	1.0	.8	1.2	1.7	7.2
30	2.0	.....	5.9	7.8	7.3	3.0	1.5	1.0	.8	1.2	1.5	5.0
31	2.0	.....	5.9	.....	7.0	.....	1.4	1.0	.....	1.2	.....	4.5

Rating table for Feather River at Oroville, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.8	1,300	3.0	2,750	5.2	5,660	9.5	18,900
1.0	1,400	3.2	2,950	5.4	6,020	10.0	21,200
1.2	1,510	3.4	3,150	5.6	6,400	10.5	23,500
1.4	1,620	3.6	3,365	5.8	6,800	11.0	25,800
1.6	1,735	3.8	3,595	6.0	7,200	11.5	28,100
1.8	1,855	4.0	3,825	6.5	8,300	12.0	30,400
2.0	1,975	4.2	4,095	7.0	9,500	12.5	32,700
2.2	2,115	4.4	4,365	7.5	10,900	13.0	35,000
2.4	2,255	4.6	4,660	8.0	12,500	14.0	39,600
2.6	2,410	4.8	4,980	8.5	14,400		
2.8	2,580	5.0	5,300	9.0	16,600		

Estimated monthly discharge of Feather River at Oroville, Cal.

[Drainage area, 3,350 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
uary	2,325	1,975	1,998	122,852	0.60	0.69
ruary	38,680	1,975	19,545	1,085,474	5.83	6.07
rch	24,420	7,000	11,148	685,464	3.33	3.84
ril	39,600	8,300	19,485	1,159,438	5.82	6.49
y	16,600	9,020	12,110	744,615	3.61	4.16
ie	10,900	2,750	5,609	333,759	1.67	1.86
y	2,750	1,620	2,098	129,001	.63	.73
gust	1,620	1,400	1,535	94,383	.46	.53
tember	1,400	1,300	1,323	78,724	.39	.44
tober	3,150	1,300	1,503	92,416	.45	.52
vember	14,400	1,510	3,481	207,134	1.04	1.16
cember	25,800	1,565	6,287	386,573	1.88	2.17
The year	39,600	1,300	7,177	5,119,833	2.14	28.66

STONY CREEK NEAR FRUTO, CAL.

On January 30, 1901, a gaging station was established by Burt Cole Julian's ranch, 6 miles northwest of the town of Fruto, Cal., to termine the amount of water available for storage. The observer Mrs. Lee Julian.

During 1902 the following discharge measurements were made by G. Bennett:

January 26: Gage height, 3.90 feet; discharge, 126 second-feet.
February 28: Gage height, 10.00 feet; discharge, 7,336 second-feet.
May 8: Gage height, 5.33 feet; discharge, 1,080 second-feet.
September 24: Gage height, 3.00 feet; discharge, 14 second-feet.

Daily gage height, in feet, of Stony Creek at Julian's ranch, near Fruto, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	4.0	3.9	9.2	5.4	5.1	4.6	2.9	2.7	2.8	3.5	3.9	5.9
2	4.1	4.0	9.8	5.5	5.0	4.5	2.9	2.7	2.8	3.5	3.9	5.9
3	4.0	4.0	8.3	5.6	4.9	4.4	2.9	2.7	2.8	3.5	3.9	5.8
4	4.0	3.9	7.9	5.7	4.9	4.4	2.9	2.7	2.8	3.5	3.9	5.7
5	4.0	4.0	7.3	5.8	4.8	4.4	2.9	2.7	2.8	3.5	3.9	7.2
6	3.9	4.7	7.6	7.0	4.8	4.3	2.8	2.7	2.8	3.5	4.0	5.7
7	3.9	6.9	7.6	8.5	5.3	4.3	2.7	2.7	2.8	3.5	4.0	5.6
8	3.9	7.5	8.8	7.6	5.5	4.3	2.7	2.7	2.8	3.6	4.8	5.5
9	3.9	7.5	8.4	7.3	5.4	4.2	2.7	2.7	2.8	3.6	8.7	5.6
10	3.9	7.9	7.5	7.0	5.3	4.2	2.7	2.7	2.9	3.6	7.8	5.7
11	3.9	8.8	7.3	6.8	5.2	4.1	2.7	2.7	2.9	3.6	6.7	5.7
12	3.9	7.5	7.0	6.5	5.3	4.1	2.7	2.7	2.9	3.6	6.1	5.6
13	3.9	7.0	7.0	6.0	5.3	4.1	2.7	2.7	2.9	3.6	6.0	5.6
14	3.9	7.2	7.0	6.1	5.3	4.0	2.7	2.7	2.9	3.7	5.9	5.6
15	3.9	8.3	7.0	6.1	5.1	4.0	2.7	2.7	2.9	3.7	5.9	5.5
16	3.9	7.5	7.0	6.0	5.0	3.9	2.7	2.7	2.9	3.7	5.9	5.5
17	3.9	7.4	6.9	5.9	5.0	3.8	2.7	2.7	2.9	3.7	6.0	5.5
18	3.9	6.7	6.8	5.8	5.0	3.8	2.7	2.7	2.9	3.7	7.2	5.5
19	3.9	6.7	6.6	5.7	4.9	3.7	2.7	2.7	2.9	3.7	7.8	5.4
20	3.9	6.9	6.6	5.6	4.8	3.6	2.7	2.7	2.9	3.7	7.1	5.4
21	3.9	7.6	6.5	5.7	4.8	3.5	2.7	2.7	2.9	3.7	6.7	5.3
22	4.0	8.3	6.5	5.5	4.7	3.4	2.7	2.7	2.9	3.8	6.6	5.2
23	4.0	10.1	5.6	5.6	4.7	3.4	2.7	2.7	2.9	3.8	6.5	5.2
24	4.0	13.2	5.6	5.5	4.6	3.3	2.7	2.7	3.0	4.2	6.5	5.1
25	3.9	12.6	5.5	5.6	4.6	3.3	2.7	2.7	3.0	4.3	6.4	5.4
26	3.9	11.2	5.5	5.4	4.6	3.2	2.7	2.8	3.0	4.2	6.4	6.1
27	3.9	12.4	5.4	5.3	4.5	2.8	2.7	2.8	3.0	4.1	6.3	5.8
28	3.9	10.1	5.4	5.3	4.5	2.8	2.7	2.8	3.0	4.0	6.2	5.8
29	3.9	.....	5.4	5.2	4.4	2.8	2.7	2.8	3.0	4.0	6.1	5.8
30	3.9	.....	5.4	5.1	4.5	2.8	2.7	2.8	3.0	4.0	6.0	5.7
31	3.9	.....	5.4	.....	4.6	.....	2.7	2.8	.....	3.9	.....	5.6

Rating table for Stony Creek at Julian's ranch, near Fruto, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.8	5	4.6	370	6.4	1,835	8.5	4,680
3.0	14	4.8	490	6.6	2,050	9.0	5,510
3.2	27	5.0	620	6.8	2,275	9.5	6,410
3.4	44	5.2	765	7.0	2,510	10.0	7,400
3.6	67	5.4	920	7.2	2,765	10.5	8,400
3.8	94	5.6	1,080	7.4	3,035	11.0	9,450
4.0	125	5.8	1,250	7.6	3,315	11.5	10,550
4.2	185	6.0	1,430	7.8	3,605	12.0	11,700
4.4	270	6.2	1,625	8.0	3,900	13.0	14,150

Estimated monthly discharge of Stony Creek at Julian's ranch, near Fruto, Cal.

[Darinage area, 760 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
ınuary	150	109	114	7,010	0.15	0.17
ɔbruary	14,650	109	4,201	233,312	5.53	5.76
arch	7,000	920	2,588	159,130	3.41	3.93
pril	4,680	690	1,522	90,565	2.00	2.23
ay	1,000	270	578	35,540	.76	.88
ıne	370	5	132	7,855	.17	.19
ıly	9	2	3	184	.00	.00
ugust	5	2	3	184	.00	.00
ɔtember	14	5	9	536	.01	.01
ctober	225	55	92	5,657	.12	.14
ovember	5,005	109	1,584	94,255	2.08	2.32
ecember	2,765	690	1,132	69,604	1.49	1.72
The year	14,650	2	997	703,832	1.31	17.35

ıCRAMENTO RIVER AT JELLYS FERRY AND AT IRON CANYON, NEAR RED BLUFF, CAL.

The gaging station at Jellys Ferry, which is located 12 miles above e town of Red Bluff, was established April 30, 1895. The right bank the river is high, but the left bank is liable to overflow when the 'er rises above the 25-foot mark. The river has been known to reach ɔ 33-foot mark. Because of the liability to overflow, it was deemed visable to select a new gaging station where the water at flood stage uld be more confined. A point in Iron Canyon, where the river had ɔn gaged by the State engineering department in 1879 and by the nmissioner of public works in 1893–94, was chosen as a new gaging tion. The river stage rod used by the commissioner of public rks was still in place and has been used in making river height ɜervations since January 28, 1902, the date upon which the observa- ns were begun. The river at this point in lower portion of Iron nyon, 4 miles above Red Bluff, has a direct course for 2 or 3 miles. e width between banks at low water is about 500 feet. The depth water at low stages averages 6 feet with a maximum depth of 9 feet. e banks are steep and firm. The river flows in a bed of coarse ıvel and cobbles with here and there a small bowlder. The bed

rock is lava. Discharge measurements are made from a cable feet long, which is anchored in the lava rock that forms the wal the canyon. The observer at Jellys Ferry was A. A. Sergison; Iron Canyon, F. A. Wilcox.

Daily gage height, in feet, of Sacramento River at Jellys Ferry, near Bluff, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Ju
1902.						
1	5.7	5.5	19.6	9.0	11.4	
2	6.0	5.8	21.3	9.1	10.5	
3	6.3	5.5	16.7	9.7	9.9	
4	5.8	6.5	15.3	11.2	9.7	
5	5.8	8.1	14.2	10.9	9.4	
6	5.8	9.4	17.6	11.3	9.6	
7	5.7	16.0	15.8	18.3	11.5	
8	5.7	21.9	19.8	17.6	11.1	
9	5.7	25.2	21.9	14.5	10.7	
10	5.7	32.6	17.1	13.0	10.5	
11	5.6	29.6	15.1	12.4	10.2	
12	5.6	26.0	14.0	11.5	9.9	
13	5.6	19.3	15.1	11.0	10.6	
14	5.5	18.3	12.6	10.9	11.7	
15	5.5	23.8	11.9	10.9	12.3	
16	5.6	22.6	11.4	10.8	11.1	
17	5.5	23.1	11.1	10.9	10.6	
18	5.5	20.9	10.9	10.9	10.2	
19	5.4	17.5	11.0	11.3	9.7	
20	5.5	15.5	10.4	11.0	9.4	
21	5.9	17.1	10.6	10.6	9.1	
22	5.9	20.8	10.2	10.1	8.9	
23	5.8	21.2	10.3	9.8	8.8	
24	6.2	32.7	9.9	9.6	8.8	
25	5.9	32.0	9.6	9.8	8.8	
26	5.7	28.8	9.4	9.3	8.8	
27	5.6	25.9	9.2	9.2	9.1	
28	5.5	21.3	9.0	8.9	9.1	
29	5.5	.....	8.9	10.7	8.9	
30	5.5	.....	8.9	10.4	8.5	
31	5.5	.....	8.9	.....	8.4	...

Rating table for Sacramento River at Jellys Ferry, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.0	2,400	6.8	8,070	12.0	24,400	22.0	76,800
4.2	2,670	7.0	8,630	12.5	26,400	23.0	83,400
4.4	2,970	7.2	9,200	13.0	28,400	24.0	90,000
4.6	3,290	7.4	9,800	13.5	30,400	25.0	96,600
4.8	3,630	7.6	10,400	14.0	32,400	26.0	103,200
5.0	3,980	7.8	11,000	14.5	34,600	27.0	109,800
5.2	4,360	8.0	11,600	15.0	36,800	28.0	116,400
5.4	4,760	8.5	13,100	15.5	39,200	29.0	123,000
5.6	5,170	9.0	14,600	16.0	41,600	30.0	129,600
5.8	5,590	9.5	16,100	17.0	46,600	31.0	136,200
6.0	6,030	10.0	17,600	18.0	52,300	32.0	142,800
6.2	6,500	10.5	19,200	19.0	58,200	33.0	149,400
6.4	7,000	11.0	20,800	20.0	64,200	34.0	156,000
6.6	7,530	11.5	22,600	21.0	70,400	35.0	162,600

Estimated monthly discharge of Sacramento River at Jellys Ferry, near Red Bluff, Cal.

[Drainage area, 9,134 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	6,750	4,760	5,376	330,557	0.59	0.68
February	147,420	4,965	69,423	3,855,558	7.60	7.91
March	76,160	14,300	31,213	1,919,213	3.42	3.94
April	54,070	14,300	22,096	1,314,803	2.42	2.70
May	25,600	12,800	17,453	1,073,143	1.91	2.20
June	12,500	6,030	8,758	521,137	.96	1.07

Discharge measurements of Sacramento River at Iron Canyon, near Red Bluff, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1901.		*Feet.*	*Second-feet.*
October 30	S. G. Bennett	1.02	5,187
December 13	do	2.68	9,651
1902.			
January 28	do	1.35	5,912
February 12	Wm. F. Luning	20.60	110,824
March 3	S. G. Bennett	10.60	41,570
May 10	do	5.50	18,927
September 13	C. A. Miller	.84	4,425
December 31	S. G. Bennett	3.20	9,858

Daily gage height, in feet, of Sacramento River at Iron Canyon, near Red Bluff, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	.....	1.3	12.3	4.2	5.8	4.0	1.9	1.4	1.1	1.0	1.4	2.6
2	.....	1.3	11.0	4.5	6.0	4.0	1.8	1.4	1.0	1.0	1.5	2.5
3	.....	1.3	9.4	4.8	6.0	4.0	1.7	1.4	1.0	1.0	1.5	2.4
4	.....	1.3	9.0	4.9	5.0	3.5	1.6	1.4	1.0	1.0	1.4	2.4
5	.....	3.6	8.0	5.8	4.8	3.2	1.6	1.4	1.0	1.0	1.3	2.3
6	.....	4.4	9.3	6.0	4.7	3.2	1.6	1.4	1.0	1.0	1.3	3.0
7	.....	9.4	9.8	12.7	6.5	3.2	1.6	1.3	1.0	1.0	1.8	6.0
8	.....	15.2	13.0	11.0	6.3	3.2	1.6	1.3	1.0	1.0	4.9	5.5
9	.....	17.4	14.0	9.7	5.9	3.2	1.6	1.3	1.0	1.0	17.5	5.0
10	.....	23.6	10.0	7.6	5.8	3.0	1.6	1.3	1.0	1.0	21.4	10.0
11	.....	22.7	9.0	6.7	5.4	3.0	1.6	1.3	1.0	1.0	8.5	9.0
12	.....	23.0	8.0	6.0	5.3	3.0	1.6	1.3	1.0	1.0	5.9	7.9
13	.....	14.1	7.5	5.9	5.2	3.0	1.6	1.3	1.0	1.0	5.0	7.5
14	.....	14.8	7.0	5.9	6.7	3.0	1.6	1.3	1.0	1.0	5.3	6.5
15	.....	17.5	6.8	5.9	6.8	3.0	1.6	1.3	1.0	1.0	5.5	4.9
16	.....	16.5	6.2	5.9	5.7	3.3	1.6	1.3	1.0	1.0	6.0	4.5
17	.....	16.0	6.0	5.9	6.5	3.2	1.5	1.3	1.0	1.0	6.7	4.1
18	.....	13.0	6.0	5.9	5.5	2.6	1.5	1.3	1.0	1.0	5.8	3.8
19	.....	11.0	6.0	6.3	4.8	3.0	1.5	1.3	1.0	1.0	5.8	3.6
20	.....	10.0	5.7	6.3	4.8	2.9	1.5	1.3	1.0	1.0	5.2	3.4
21	.....	11.3	5.3	5.5	4.2	2.8	1.4	1.3	1.0	1.0	5.0	3.3
22	.....	13.2	5.2	5.5	4.3	2.7	1.4	1.3	1.0	1.7	4.5	3.2
23	.....	15.3	5.1	5.4	3.0	2.6	1.4	1.3	1.0	1.7	4.0	3.9
24	.....	24.8	5.0	5.0	4.4	2.5	1.4	1.3	1.0	3.5	3.7	3.9
25	.....	24.0	4.8	5.1	4.4	2.4	1.4	1.3	1.0	3.4	3.5	3.9
26	.....	24.1	4.7	5.0	4.4	2.3	1.4	1.3	1.0	2.5	3.4	9.6
27	.....	20.3	4.5	5.0	4.3	2.2	1.4	1.3	1.0	1.8	3.0	7.8
28	1.3	14.6	4.4	5.0	4.3	2.0	1.4	1.2	1.0	2.0	2.8	6.1
29	1.3	.....	4.3	4.5	4.2	1.9	1.4	1.2	1.0	1.7	2.7	5.1
30	1.3	.....	4.2	5.8	4.2	1.9	1.4	1.2	1.0	1.7	2.6	4.6
31	1.3	.....	4.2	.....	4.3	.....	1.4	1.2	.....	1.7	.....	4.6

Rating table for Sacramento River at Iron Canyon, near Red Bluff, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	5,000	5.0	17,100	9.0	34,300	13.0	55,600
1.2	5,440	5.2	17,900	9.2	35,260	13.2	56,800
1.4	5,880	5.4	18,700	9.4	36,220	13.4	58,000
1.6	6,340	5.6	19,500	9.6	37,180	13.6	59,220
1.8	6,820	5.8	20,300	9.8	38,140	13.8	60,460
2.0	7,300	6.0	21,100	10.0	39,100	14.0	61,700
2.2	7,840	6.2	21,940	10.2	40,100	14.5	64,900
2.4	8,380	6.4	22,780	10.4	41,100	15.0	68,200
2.6	8,950	6.6	23,620	10.6	42,120	15.5	71,600
2.8	9,550	6.8	24,460	10.8	43,160	16.0	75,100
3.0	10,150	7.0	25,300	11.0	44,200	16.5	78,600
3.2	10,790	7.2	26,180	11.2	45,280	17.0	82,200
3.4	11,430	7.4	27,060	11.4	46,360	18.0	89,700
3.6	12,090	7.6	27,940	11.6	47,460	19.0	97,600
3.8	12,770	7.8	28,820	11.8	48,580	20.0	105,900
4.0	13,450	8.0	29,700	12.0	49,700	21.0	114,600
4.2	14,150	8.2	30,620	12.2	50,860	22.0	123,700
4.4	14,850	8.4	31,540	12.4	52,020	23.0	133,200
4.6	15,580	8.6	32,460	12.6	53,200	24.0	143,100
4.8	16,340	8.8	33,380	12.8	54,400	25.0	153,400

Estimated monthly discharge of Sacramento River at Iron Canyon, near Red Bluff, Cal.

[Drainage area, 9,295 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
nuary [a]	6,750	4,760	5,376	330,557	0.59	0.68
bruary	151,320	5,660	69,154	3,840,619	7.44	7.75
arch	61,700	14,150	27,371	1,682,977	2.94	3.39
pril	53,800	14,150	21,992	1,308,615	2.37	2.64
ay	24,460	10,150	17,803	1,094,664	1.92	2.21
ne	13,450	7,060	9,998	594,922	1.08	1.20
ly	7,060	5,880	6,192	380,731	.67	.77
gust	5,880	5,440	5,674	348,881	.61	.70
ptember	5,220	5,000	5,007	297,937	.54	.60
tober	11,750	5,000	5,931	364,683	.64	.74
vember	118,200	5,660	19,767	1,176,218	2.13	2.38
cember	39,100	8,110	17,506	1,076,402	1.88	2.17
The year	151,320	4,760	17,648	12,497,206	1.90	25.23

[a] Discharge at Jellys Ferry for January.

TUOLUMNE RIVER AT LAGRANGE, CAL.

The station, established August 29, 1895, is located at the wag bridge in the town of Lagrange, Cal. It is below the high dam of t Turlock and Modesto irrigation districts and also below the head the canal of the Lagrange Ditch and Hydraulic Mining Compan which diverts water from the left bank of the river 15 miles abo Lagrange dam. The flow through this canal for 1902 was betwe 4 and 5 cubic feet per second.

The channel at the gaging station, both above and below the brid is straight for several hundred feet and the velocity of the stream quite uniform. Both banks are high and not subject to overflo For the last few years the channel seems to be gradually washing o The observer is Annie P. McGinn.

During 1902 the following discharge measurements were made S. G. Bennett and L. M. Lawson:

	Second-feet.
March 6:	
Gage height, 6.00 feet; discharge	2,351
Turlock Canal	103
Lagrange Ditch and Hydraulic Mining Company's canal	5
Total	2,459
May 13:	
Gage height, 8.35 feet; discharge	9,476
Turlock Canal	253
Lagrange Ditch and Hydraulic Mining Company's canal	5
Total	9,734
August 27:	
Gage height, 3.50 feet; discharge	15
Turlock Canal	105
Lagrange Ditch and Hydraulic Mining Company's canal	4
Total	124

Daily gage height, in feet, of Tuolumne River at Lagrange, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902												
	4.4	4.4	6.0	5.6	6.8	7.7	6.2	4.4	3.5	3.6	4.4	4.6
	4.3	4.4	6.7	5.6	6.6	7.2	6.1	4.4	4.0	3.7	4.4	4.6
	5.0	4.4	6.5	5.5	6.6	7.1	5.9	4.2	4.2	3.6	4.4	4.5
	5.1	4.4	6.1	5.6	6.5	7.4	5.9	4.1	4.0	3.6	4.3	4.6
	4.8	4.4	5.9	5.8	6.8	7.7	5.5	4.0	4.0	3.6	4.3	4.8
	4.6	4.3	5.9	6.6	7.0	7.9	5.5	3.8	4.0	3.6	4.4	5.2
	4.5	4.4	5.8	9.2	7.4	7.7	5.3	3.9	4.0	3.6	4.4	5.3
	4.4	4.4	6.3	8.9	8.1	8.0	5.2	3.8	3.9	3.7	4.3	5.1
	4.5	4.9	7.4	7.6	8.4	8.9	5.3	4.1	3.9	3.7	4.4	5.1
	4.7	4.8	6.6	7.1	8.4	8.7	5.4	4.0	3.9	3.7	5.9	5.0
	4.6	4.8	6.1	6.9	8.3	8.4	5.4	3.8	4.0	3.6	6.2	6.2
	4.5	4.8	6.1	6.8	8.0	8.6	5.3	4.0	4.0	3.6	5.6	5.8
	4.5	4.8	6.0	6.9	7.7	8.5	5.3	4.1	3.9	3.6	5.2	5.5
	4.5	4.8	5.9	7.1	7.4	8.0	5.2	4.1	4.0	3.7	5.1	5.4
	4.5	5.0	5.7	7.2	7.3	7.8	5.1	4.2	4.0	3.7	4.9	5.3
	4.4	5.6	5.7	7.3	7.4	7.7	5.2	4.1	3.9	3.7	4.9	5.1
	4.4	5.5	5.7	7.4	7.5	7.6	5.1	4.0	4.0	3.6	4.7	5.0
	4.4	5.4	5.8	7.6	7.5	7.3	4.9	3.9	3.9	3.6	4.8	4.9
	4.4	5.4	5.7	7.8	7.2	7.4	4.9	3.9	3.9	3.6	4.8	4.9
	4.3	5.3	5.5	8.5	6.6	7.5	5.0	3.8	4.0	3.6	5.0	4.8
	4.4	5.2	5.5	8.0	6.2	7.6	5.0	3.7	4.0	3.5	4.9	4.7
	4.3	5.7	5.5	7.6	6.1	7.5	4.9	3.5	3.9	3.5	4.9	4.8
	4.2	5.5	5.7	7.2	6.3	7.5	4.8	3.4	3.8	3.6	4.8	4.9
	4.3	5.8	5.7	6.9	6.8	7.3	4.8	3.4	3.9	3.7	4.9	4.9
	4.4	6.4	5.5	6.0	7.1	7.1	4.8	3.5	3.8	4.8	4.9	4.9
	4.5	7.3	5.5	6.0	8.0	7.0	4.8	3.5	3.8	4.6	4.8	5.0
	4.4	7.7	5.4	5.6	8.5	6.8	4.7	3.5	3.8	4.5	4.8	5.0
	4.3	7.6	5.5	6.0	8.9	6.4	4.6	3.4	3.8	4.6	4.8	4.9
	4.4	.....	5.7	6.1	8.6	6.4	4.7	3.3	3.7	4.5	4.9	4.9
	4.4	.....	5.7	6.5	8.8	6.4	4.7	3.5	3.7	4.6	4.8	4.8
	4.3	.....	5.6	.....	8.9	.....	4.5	3.4	.....	4.5	.....	4.8

Rating table for Tuolumne River at Lagrange, Cal., for 1902.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
7	5.0	750	6.6	3,610	8.2	8,580
25	5.2	950	6.8	4,100	8.4	9,350
55	5.4	1,180	7.0	4,630	8.6	10,140
115	5.6	1,480	7.2	5,200	8.8	10,950
200	5.8	1,850	7.4	5,810	9.0	11,780
300	6.0	2,260	7.6	6,450	9.2	12,630
410	6.2	2,690	7.8	7,120	9.4	13,500
560	6.4	3,140	8.0	7,830		

TURLOCK CANAL.

The Turlock canal, the property of the Turlock Irrigation District, takes water from the left bank of the Tuolumne River at the Lagrange dam. This canal was designed to carry 1,500 second-feet and to irrigate a large area of fertile land in the vicinity of Turlock and Ceres, Stanislaus County, Cal. During 1898 water was first turned into the canal in small quantities and used for puddling the banks. A record of the gage height has been kept since July, 1899. Meter measurements are made when the gaging station on Tuolumne River at Lagrange is visited, and Morgan flume, or flume No. 2, has been rated. The observer is J. L. Montgomery.

During 1902 the following discharge measurements were made by S. G. Bennett and L. M. Lawson:

May 13: Gage height, 2.92 feet; discharge, 253 second-feet.
July 23: Gage height, 3.00 feet; discharge, 260 second-feet.
Aug. 27: Gage height, 2.60 feet; discharge, 105 second-feet.

Daily gage height, in feet, of Turlock canal at Lagrange, Cal.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1902.							
1	[a]	3.1	0.0	3.7	3.8	3.9	1.3
2	.....	3.1	0.0	3.7	3.8	3.9	[b]
3	.....	3.1	3.0	3.7	3.8	3.7	.....
4	.....	3.1	3.0	3.7	3.8	3.7	.....
5	.....	3.1	3.4	3.7	3.8	3.7	.....
6	.....	3.1	3.5	3.7	3.8	3.8	.....
7	2.3	3.2	3.5	3.7	3.9	3.9	.....
8	2.0	3.2	3.5	3.7	4.0	3.9	.....
9	0.0	3.2	3.5	3.7	4.0	3.9	.....
10	0.0	3.2	3.5	3.7	4.0	3.9	.....
11	2.4	3.2	3.5	3.7	4.0	4.0	.....
12	2.6	3.2	3.5	3.7	4.0	4.0	.....
13	2.6	3.2	3.0	3.7	4.0	4.0	.....
14	2.0	3.2	3.0	3.7	4.0	3.8	.....
15	2.8	3.2	3.0	3.7	4.0	3.8	.....
16	2.8	3.2	3.0	3.7	4.0	3.8	.....
17	0.0	3.2	3.6	3.7	3.2	3.8	.....
18	3.0	2.5	3.6	3.7	2.7	4.0	.....
19	3.1	2.5	3.6	3.7	3.6	3.9	.....
20	3.1	2.4	3.6	3.7	3.6	3.9	.....
21	3.1	3.4	3.6	3.7	3.6	3.7	.....
22	3.1	3.4	3.6	3.8	3.6	3.6	.....
23	3.1	3.4	3.6	3.8	3.6	3.4	.....
24	3.1	3.4	3.6	3.8	3.6	3.5	.....
25	3.1	3.5	3.6	3.8	3.6	3.5	.....
26	3.1	3.5	3.6	3.8	3.6	2.8	.....
27	3.1	3.5	3.3	3.8	3.6	2.8	.....
28	0.0	0.0	2.9	3.8	3.6	2.7	.....
29	0.0	0.0	3.6	3.8	3.6	2.7	.....
30	2.4	0.0	3.6	3.8	3.6	2.6	.....
31	3.0	.....	3.6	.....	3.6	2.6	.....

[a] No record Jan. 1 to Mar. 6. [b] Sept. 2 to Dec. 31 no water in canal; making repairs.

Rating table for Turlock canal at Lagrange, Cal., for 1902.

MARCH 7 TO JULY 31.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.0	113	2.5	182	3.0	268	3.5	360
2.1	125	2.6	198	3.1	286	3.6	380
2.2	138	2.7	215	3.2	304	3.7	400
2.3	152	2.8	232	3.3	322	3.8	420
2.4	166	2.9	250	3.4	340	4.0	460

APPROXIMATE TABLE FOR AUGUST.

2.6	105	3.0	175	3.4	247	3.8	327
2.7	122	3.1	193	3.5	267	3.9	347
2.8	139	3.2	211	3.6	287	4.0	367
2.9	157	3.3	229	3.7	307		

Estimated monthly discharge of Tuolumne River at Lagrange, Cal.

[Drainage area, 1,501 square miles.]

Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
1902.			
anuary	850	200	352
ebruary	6,780	250	1,443
arch	5,810	1,180	2,103
pril	12,630	1,320	4,735
ay	11,360	2,470	6,334
ne	11,360	3,140	6,519
ly	2,690	350	998
ugust	300	0	91
eptember	200	35	89
tober	560	15	113
ovember	2,690	250	676
ecember	2,690	350	809
The year	12,630	0	2,022

Estimated monthly discharge of Turlock canal at Lagrange, Cal.

Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
1902.			
January	0	0	0
February	0	0	0
March	286	0	187
April	360	0	268
May	380	0	322
June	420	400	406
July	460	215	405
August	367	105	287
September	47	0	2
October	0	0	0
November	0	0	0
December	0	0	0
The year	460	0	156

Estimated monthly combined discharge of Tuolumne River and Turlock canal at Lagrange, Cal.

[Drainage area, 1,501 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	850	200	352	21,644	0.23	0.27
February	6,780	250	1,443	80,140	.96	1.0[illegible]
March	5,810	1,320	2,290	140,807	1.53	1.7[illegible]
April	12,934	1,606	5,003	297,699	3.33	3.7[illegible]
May	11,740	2,850	6,656	409,262	4.43	5.1[illegible]
June	11,760	3,560	6,925	412,066	4.61	5.1[illegible]
July	3,110	730	1,403	86,267	.93	1.0[illegible]
August	647	112	378	23,242	.25	.2[illegible]
September	200	35	91	5,415	.06	.0[illegible]
October	560	15	113	6,948	.08	.0[illegible]
November	2,690	250	676	40,225	.45	.5[illegible]
December	2,690	350	809	49,743	.54	.6[illegible]
The year	12,934	15	2,178	1,573,458	1.45	19.[illegible]

MERCED RIVER ABOVE MERCED FALLS, CAL.

measurement of this stream was undertaken in response to us requests from mining and irrigation interests. The mid- r flow of the stream is less than the combined capacity of the on and power canals taking water in the vicinity of Snelling. ging station at a point 1 mile above Merced Falls was estab- April 6, 1901. Meter measurements are made from a cable. server is Charles Siegfeldt.

ng 1902 the following discharge measurements were made by ennett and L. M. Lawson:

arch 6: Gage height, 10.10 feet; discharge, 1,302 second-feet.
ay 13: Gage height, 12.15 feet; discharge, 5,413 second-feet.
ptember 3: Gage height, 8.10 feet; discharge, 109 second-feet.

aily gage height, in feet, of Merced River above Merced Falls, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	8.6	8.4	10.5	9.7	10.8	11.6	10.0	8.7	8.1	7.8	8.1	8.5
.....	8.7	8.5	12.3	9.8	10.8	11.4	9.9	8.7	8.0	7.8	8.1	8.5
.....	9.1	8.5	11.0	9.7	10.9	11.3	9.8	8.6	8.1	7.8	8.1	8.5
.....	8.9	8.5	10.5	9.6	10.9	11.4	9.6	8.6	8.1	7.8	8.1	8.5
.....	8.9	8.5	10.2	9.7	1.	11.9	9.5	8.5	8.1	7.8	8.1	8.3
.....	8.8	8.5	10.1	9.9	11.4	12.0	9.4	8.5	8.1	7.8	8.0	8.6
.....	8.8	8.5	10.0	11 8	1.5	12.0	9.3	8.5	8.0	7.8	8.0	8.9
.....	8.7	8.6	10.0	12.4	1.9	12.3	9.3	8.6	8.0	7.8	8.1	8.8
.....	8.7	8.7	12.5	11.8	12.	12.	9.3	8.5	8.0	7.8	8.1	10.2
.....	8.7	8.7	11.5	5	12.	12.3	9.3	8.8	8.0	7.9	8.4	8.8
.....	8.6	8.6	10.6	11 0	12.0	12.	9.4	8.8	8.0	7.8	10.0	9.3
.....	8.6	8.7	10.4	10.8	12.	12.	9.3	8.9	8.0	7.8	9.2	9.5
.....	8.7	8.8	10.1	10.9	12.3	11.9	9.3	8.9	8.0	7.8	8.8	9.2
.....	8.6	8.8	10.1	11.0	11.6	11.4	9.3	8.7	8.0	7.8	8.7	9.0
.....	8.7	8.7	9.7	11.2	11.3	11.4	9.2	8.7	8.0	7.8	8.7	8.8
.....	8.6	8.9	9.6	11.1	11.1	11.2	9.2	8.5	8.0	7.9	8.6	8.8
.....	8.6	9.2	9.7	11.3	11.6	11.1	9.1	8.5	7	7.8	8.6	8.7
.....	8.6	9.3	9.8	11.8	11.8	11.1	8.9	8.4	9	7.8	8.6	8.7
.....	8.6	9.1	9.6	12.2	11.2	11.1	9.0	8.4	8.0	7.8	9.3	8.7
.....	8.6	9.0	9.6	11.9	11.0	11.1	8.9	8.	8.0	7.8	9.0	8.5
.....	8.6	9.0	9.6	11.4	10.8	11.1	9.0	8.3	8.	7.8	8.8	8.6
.....	8.5	9.5	9.4	10.9	10.8	11.0	8.9	8.3	8.0	7.8	8.8	8.6
.....	8.5	9.4	9.4	10.8	11.0	10.9	8.9	8.2	8.	7.9	8.7	8.6
.....	8.5	10.5	9.5	10.7	11.3	10.7	8.9	8.2	9	8.2	8.7	8.6
.....	8.6	10.8	9.4	10.5	11.9	10.6	8.9	8.2	9	8.8	8.6	8.6
.....	8.6	11.3	9.3	10.5	11.7	10.5	8.9	8.		8.4	8.6	8.6
.....	8.5	11.8	9.3	10.5	12.4	10.4	8.8	8.		8.4	8.5	8.7
.....	8.5	11.3	9.2	10.4	12.7	10.1	8.9	8.1	9	8.3	8.7	8.8
.....	8.5	.....	9.4	10.5	12.7	10.1	8.8	8.		8.2	8.6	8.7
.....	8.5	.....	9.5	10.8	12.6	10.2	8.8	8.		8.1	8.6	8.6
.....	8.5	.....	9.6	.....	12.4	.....	8.8	8.		8.1	.....	8.6

Rating table for Merced River above Merced Falls, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharg
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
7.8	65	8.9	320	10.0	1,110	11.2	2,840
7.9	75	9.0	360	10.1	1,220	11.4	3,200
8.0	90	9.1	410	10.2	1,340	11.6	3,590
8.1	110	9.2	460	10.3	1,470	11.8	4,020
8.2	130	9.3	520	10.4	1,600	12.0	4,480
8.3	150	9.4	580	10.5	1,740	12.2	4,960
8.4	170	9.5	650	10.6	1,880	12.4	5,460
8.5	195	9.6	730	10.7	2,030	12.6	5,980
8.6	220	9.7	810	10.8	2,180	12.8	6,500
8.7	250	9.8	900	10.9	2,340		
8.8	280	9.9	1,000	11.0	2,500		

Estimated monthly discharge of Merced River above Merced Falls, Cal.

[Drainage area, 1,090 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dept incl
1902.						
January	410	195	236	14,511	0.22	
February	4,020	170	749	41,597	.69	
March	5,720	460	1,364	83,869	1.25	
April	5,460	730	2,457	146,202	2.25	
May	6,240	2,180	3,795	233,345	3.48	
June	5,460	1,220	3,142	186,962	2.88	
July	1,110	280	481	29,576	.44	
August	320	110	191	11,744	.18	
September	110	65	88	5,236	.08	
October	280	65	90	5,534	.08	
November	1,110	90	246	14,638	.23	
December	1,340	195	303	18,631	.28	
The year	6,240	65	1,095	791,845	1.01	1

KING RIVER AT KINGSBURG, CAL.

ɜ station was established in 1879 by the engineering department ɔ Southern Pacific Company. No meter measurements have nade since 1898 except a low-water measurement in 1902, because . found impossible to construct a satisfactory rating table, on nt of the changes in gage heights caused by the raising and ing of the head gate of the Peoples Canal, which takes water King River a few miles below the gaging station. The gage ts for 1902 have been furnished by William Hood, chief engineer Southern Pacific Company. Alf. Thompson was the observer.

Daily gage height, in feet, of King River, at Kingsburg, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
	3.8	3.3	4.3	4.1	3.8	7.5	3.8	2.7	1.6	1.3	1.8	4.7
	3.8	3.3	3.3	4.2	3.3	6.7	3.6	2.7	1.7	1.3	1.7	4.7
	3.8	3.3	6.3	3.8	3.5	6.1	3.4	2.7	1.6	1.3	1.7	4.8
	4.4	3.4	4.3	3.8	3.7	7.3	2.8	2.5	1.6	1.3	1.7	4.8
	4.4	3.4	3.3	3.8	3.8	8.0	2.3	2.5	1.6	1.3	2.0	4.8
	4.3	3.4	3.1	3.8	4.7	8.4	2.0	2.4	1.6	1.3	2.3	4.8
	4.3	3.5	4.5	3.6	4.8	9.0	2.0	2.3	1.6	1.3	2.5	4.8
	4.3	3.6	4.3	8.8	6.1	9.3	1.9	2.5	1.6	1.3	2.8	4.8
	4.0	3.7	4.9	5.9	7.8	9.4	2.7	2.4	1.6	1.3	3.3	4.9
	3.9	3.6	6.0	4.8	7.7	9.3	2.9	2.4	1.7	1.3	3.9	5.0
	3.9	3.5	4.8	4.1	7.5	8.8	3.6	2.3	1.7	1.3	5.3	5.1
	3.8	3.5	4.2	3.6	7.8	9.5	4.1	2.3	1.7	1.3	4.9	5.1
	3.8	3.6	3.8	3.7	8.3	9.5	4.3	2.3	1.7	1.3	4.5	5.0
	3.8	3.7	4.3	3.9	7.3	8.3	3.9	2.2	1.7	1.3	4.9	5.0
	3.7	3.5	4.2	4.3	6.3	7.7	3.6	2.2	1.7	1.3	4.9	5.1
	3.4	3.5	3.8	4.1	5.6	7.5	3.3	2.1	1.7	1.3	4.8	5.1
	3.4	3.6	3.8	4.5	6.3	7.0	3.3	2.0	1.7	1.3	4.6	5.0
	3.4	3.7	3.9	5.3	7.3	6.8	3.2	1.9	1.7	1.3	4.5	5.0
	3.3	3.7	4.2	6.5	6.1	6.8	3.3	1.8	1.7	1.3	4.6	5.0
	3.3	3.5	4.3	5.9	5.5	6.7	2.8	1.8	1.6	1.3	4.8	5.0
	3.3	3.5	3.9	5.1	4.8	6.7	2.9	1.8	1.6	1.3	5.1	4.8
	3.2	3.7	3.7	5.3	4.3	6.5	2.8	1.8	1.6	1.3	4.8	4.8
	3.3	3.8	3.4	3.1	4.4	6.0	2.8	1.8	1.6	1.4	4.9	5.0
	3.3	3.8	3.5	3.3	4.9	5.8	2.8	1.8	1.4	1.4	4.8	5.0
	3.3	5.6	3.5	3.3	6.1	5.3	2.8	1.8	1.4	1.7	4.8	4.9
	3.4	6.1	3.3	2.8	6.3	5.1	2.8	1.8	1.5	2.6	4.7	5.0
	3.5	5.9	3.3	2.7	7.0	4.7	3.0	1.8	1.5	2.4	4.7	5.0
	3.3	6.1	3.3	2.8	8.5	4.2	3.0	1.8	1.4	2.5	4.8	5.1
	3.4	.....	3.3	2.8	9.0	3.9	3.1	1.7	1.3	2.5	4.7	5.0
	3.4	.....	3.6	2.8	9.0	3.9	3.0	1.6	1.3	2.5	4.7	4.9
	3.4	.....	4.0	.....	8.8	.....	2.8	1.6	.....	1.8	.....	4.9

KING RIVER AT RED MOUNTAIN, NEAR SANGER, CAL.

The gaging station at Red Mountain, established September 3, 1895, is located 15 miles east of Sanger, Cal., and is near the mouth of the canyon and above all diversions. The bed of the stream is in gravel and few changes have been noted in the cross section since the establishment of the station. For the last three years the station has been considered as rated for all gage heights up to 11 feet, and few meter measurements have been made. The present rating will probably hold good until a change in the channel is caused by a violent flood. The observer is O. G. Williams.

The following discharge measurement was made in 1902 by L. M. Lawson:

September 21: Gage height, 4.00 feet; discharge, 217 second-feet.

Daily gage height, in feet, of King River at Red Mountain, near Sanger, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec
1902.												
1	4.4	4.1	5.6	6.1	7.7	8.9	7.8	5.2	4.1	3.8	4.0	4.2
2	4.4	4.2	8.3	6.1	7.8	8.9	7.8	5.2	4.0	3.8	4.0	4.3
3	4.4	4.2	6.6	6.0	8.0	9.1	7.1	5.1	4.0	3.8	3.9	4.3
4	4.4	4.1	5.9	6.1	8.1	9.9	6.7	5.0	4.0	3.7	3.9	4.3
5	4.5	4.2	5.8	6.1	8.3	10.0	6.5	4.9	4.0	3.7	3.9	4.2
6	4.4	4.2	5.8	6.1	8.9	10.0	6.4	4.9	4.0	3.7	3.9	4.3
7	4.4	4.3	5.8	13.1	8.6	10.7	6.4	5.0	4.0	3.7	3.9	4.4
8	4.4	4.3	5.6	9.1	9.3	10.7	6.5	5.1	3.9	3.7	3.8	4.4
9	4.4	4.3	7.4	8.0	9.6	11.0	6.5	5.2	4.0	3.7	3.9	4.3
10	4.3	4.2	6.3	7.7	9.8	10.9	6.4	5.2	3.9	3.7	4.0	4.3
11	4.3	4.3	5.9	7.5	9.4	10.4	6.6	5.1	4.0	3.7	5.6	5.4
12	4.4	4.2	5.8	7.6	10.0	10.9	6.3	5.0	3.9	3.7	4.9	5.2
13	4.4	4.2	5.7	7.7	10.0	11.0	6.4	5.0	4.0	3.7	4.6	4.9
14	4.3	4.2	5.7	7.9	9.3	10.1	6.2	5.0	4.0	3.7	4.5	4.5
15	4.3	4.2	5.5	8.1	8.8	10.0	6.1	4.9	4.0	3.8	4.5	4.4
16	4.3	4.3	5.5	8.2	8.8	10.0	6.0	4.7	4.0	3.7	4.3	4.4
17	4.3	4.5	5.5	8.4	9.3	9.6	5.9	4.7	4.1	3.7	4.3	4.3
18	4.3	4.8	5.7	8.7	9.4	9.6	5.8	4.6	4.0	3.7	4.3	4.4
19	4.2	4.6	5.7	9.2	8.6	9.6	5.7	4.5	4.0	3.7	4.3	4.4
20	4.2	4.4	5.7	9.0	8.2	9.7	5.6	4.5	4.0	3.7	4.7	4.3
21	4.2	4.5	5.6	8.1	7.9	9.7	5.7	4.4	4.0	3.7	4.4	4.4
22	4.2	4.7	5.6	7.9	8.0	9.3	5.6	4.3	3.9	3.7	4.4	4.3
23	4.2	4.9	5.6	7.4	8.4	8.9	5.5	4.3	3.9	3.7	4.4	4.3
24	4.3	4.8	5.5	7.4	8.6	9.0	5.5	4.2	3.9	4.5	4.4	4.3
25	4.2	5.5	5.5	7.3	9.2	9.0	5.5	4.2	3.9	4.4	4.4	4.4
26	4.3	7.3	5.5	7.1	9.1	8.7	5.4	4.1	3.9	4.1	4.4	4.3
27	4.3	6.6	5.4	7.1	9.7	8.4	5.5	4.1	3.8	4.1	4.4	4.4
28	4.2	5.8	5.5	7.2	10.3	7.9	5.6	4.1	3.8	4.1	4.4	4.5
29	4.2	.....	5.5	7.3	11.1	8.1	5.5	4.1	3.8	4.1	4.3	4.3
30	4.1	.....	5.9	7.9	10.6	8.0	5.4	4.0	3.8	4.1	4.3	4.3
31	4.1	.....	6.0	.....	10.4	.....	5.4	4.1	.....	4.0	.....	4.2

g table for King River at Red Mountain, near Sanger, Cal., for 1902.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
180	5.8	1,310	8.0	3,920	10.2	9,610
250	6.0	1,450	8.2	4,300	10.4	10,400
320	6.2	1,642	8.4	4,680	10.6	11,300
400	6.4	1,834	8.6	5,096	10.8	12,250
480	6.6	2,034	8.8	5,548	11.0	13,240
572	6.8	2,242	9.0	6,000	11.2	14,300
676	7.0	2,450	9.2	6,520	11.4	15,440
780	7.2	2,718	9.4	7,040	11.6	16,660
910	7.4	2,986	9.6	7,600	11.8	17,930
1,040	7.6	3,280	9.8	8,220	12.0	19,230
1,170	7.8	3,600	10.0	8,900		

d monthly discharge of King River at Red Mountain, near Sanger, Cal

[Drainage area, 1,742 square miles.]

lonth.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
)02.						
---- ------	520	360	440	27,055	0.25	0.29
----------	2,852	360	665	36,932	.38	.40
----------	4,490	1,040	1,420	87,312	.82	.95
------ ----	26,380	1,450	4,163	247,716	2.39	2.67
----------	13,760	3,440	6,532	401,637	3.75	4.32
------ ----	13,240	3,760	8,063	479,782	4.63	5.16
----------	3,600	1,040	1,638	100,717	.94	1.08
----------	910	320	626	38,491	.36	.42
r ---------	360	250	304	18,089	.17	.19
----------	520	215	265	16,294	.15	.17
r----------	1,170	250	451	26,836	.26	.29
r----------	1,040	400	497	30,559	.29	.33
ɔ year -----	26,380	215	2,089	1,511,420	1.20	16.27

TULE RIVER NEAR PORTERSVILLE, CAL.

aging station is located about 8 miles east of Portersville, at a ıst below the wagon bridge near the McFarland ranch and *mile above the mouth* of the South Fork of Tule River. The

station was established April 18, 1901. The gage rod is situated on the right bank of the river 100 feet below the bridge. The zero of the gage is 8 feet below a spike driven into a large cottonwood tree. The observer is Adah McFarland.

Discharge measurements of Tule River near Portersville, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
1901.			
June 28	A. E. Chandler	2.00	148
1902.			
February 5	S. G. Bennett	1.33	43
March 8	do	2.20	156
May 15	do	3.03	371
October 2	L. M. Lawson	.92	15

Daily gage height, in feet, of Tule River near Portersville, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.35	1.35	2.40	2.60	2.90	2.80	1.60	1.10	0.98	0.92	1.18	1.35
2	1.35	1.35	4.40	2.70	2.90	2.70	1.55	1.10	.98	.92	1.18	1.35
3	1.35	1.35	2.80	2.50	2.80	2.60	1.55	1.10	.96	.90	1.18	1.35
4	1.35	1.35	2.40	2.65	2.80	2.80	1.55	1.10	.94	.90	1.15	1.35
5	1.30	1.35	2.30	2.70	2.80	2.70	1.50	1.08	.94	.92	1.15	1.35
6	1.30	1.40	2.20	2.65	2.85	2.60	1.50	1.08	.92	.92	1.15	1.35
7	1.30	1.40	2.20	7.20	2.90	2.60	1.50	1.05	.92	.94	1.15	1.35
8	1.30	1.40	2.20	4.00	2.90	2.60	1.45	1.05	.92	.96	1.15	1.35
9	1.30	1.40	5.60	3.70	3.00	2.60	1.50	1.03	.92	.98	1.15	1.35
10	1.35	1.40	3.00	3.50	3.00	2.55	1.40	1.08	.92	1.00	1.40	1.35
11	1.35	1.35	2.80	3.40	3.10	2.45	1.35	1.08	.90	1.02	2.00	2.30
12	1.40	1.35	2.60	3.30	3.00	2.35	1.35	1.08	.90	1.04	1.70	1.90
13	1.40	1.35	2.50	3.20	3.05	2.35	1.30	1.06	.90	1.04	1.50	1.65
14	1.35	1.40	2.40	3.10	3.00	2.30	1.30	1.06	.90	1.03	1.45	1.55
15	1.30	1.40	2.30	3.15	3.00	2.25	1.25	1.06	.90	1.03	1.40	1.53
16	1.25	1.40	2.20	3.20	3.00	2.15	1.20	1.06	.90	1.02	1.35	1.50
17	1.30	1.40	2.00	3.30	3.00	2.10	1.20	1.06	.92	1.02	1.35	1.50
18	1.35	1.40	2.20	3.30	2.95	2.10	1.20	1.06	.92	1.02	1.35	1.48
19	1.40	1.45	2.50	3.40	2.90	2.05	1.20	1.06	.94	1.00	1.70	1.45
20	1.40	1.60	2.40	3.50	2.80	2.00	1.20	1.06	.96	1.00	1.55	1.44
21	1.35	1.60	2.35	3.70	2.70	1.90	1.20	1.06	.95	.98	1.50	1.43
22	1.35	2.00	2.25	3.00	2.65	1.85	1.20	1.08	.95	.96	1.45	1.42
23	1.35	1.75	2.35	3.00	2.65	1.80	1.20	1.08	.95	.94	1.40	1.42
24	1.40	1.80	2.35	3.00	2.60	1.75	1.18	1.04	.95	1.70	1.40	1.42
25	1.40	1.85	3.00	2.90	2.65	1.75	1.15	1.04	.95	1.40	1.40	1.42
26	1.40	4.20	3.00	2.85	2.75	1.70	1.18	1.02	.95	1.30	1.35	1.42
27	1.40	4.40	3.00	2.80	2.80	1.70	1.20	1.02	.95	1.25	1.35	1.52
28	1.35	2.70	2.60	2.85	3.00	1.65	1.20	1.01	.95	1.25	1.35	1.50
29	1.35	.....	2.30	2.90	2.90	1.60	1.18	1.00	.94	1.20	1.35	1.48
30	1.35	.....	2.30	2.90	2.80	1.60	1.15	1.00	.94	1.20	1.35	1.45
31	1.35	.....	2.50	.....	2.80	.....	1.14	1.00	.....	1.20	.....	1.43

Rating table for Tule River near Portersville, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.7	9	1.7	93	2.7	298	3.7	685
.8	11	1.8	109	2.8	324	3.8	770
.9	14	1.9	126	2.9	351	3.9	875
1.0	18	2.0	144	3.0	379	4.0	980
1.1	23	2.1	163	3.1	408	4.1	1,085
1.2	30	2.2	183	3.2	440	4.2	1,195
1.3	39	2.3	204	3.3	475	4.3	1,305
1.4	51	2.4	226	3.4	515	4.4	1,415
1.5	64	2.5	249	3.5	560	4.5	1,525
1.6	78	2.6	273	3.6	615		

Estimated monthly discharge of Tule River near Portersville, Cal.

[Drainage area, 437 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	51	34	45	2,767	0.10	0.12
ebruary	1,415	45	159	8,830	.36	.37
arch	2,735	144	362	22,259	.83	.96
pril	4,615	249	571	33,977	1.31	1.46
ay	408	273	343	21,090	.79	.91
ne	324	78	190	11,306	.43	.48
ly	78	26	43	2,644	.10	.12
ugust	23	18	21	1,291	.05	.06
ptember	17	14	15	893	.03	.03
tober	93	14	24	1,476	.05	.06
vember	144	27	50	2,975	.11	.12
cember	204	45	62	3,812	.14	.16
The year	4,615	14	157	113,320	.36	4.85

KERN RIVER NEAR BAKERSFIELD, CAL.

This station, established in 1893 by Walter Jones, chief engineer of the Kern County Land Company, is located at what is known as First Point of Measurement, 5 miles above Bakersfield and at the mouth of the canyon of the river. Miscellaneous meter measurements are taken, and an automatic gage records daily fluctuations of the river heights. A. K. Warren, the engineer in charge of this work for the Kern County Land Company, attends to the discharge measurements with accuracy and precision, and furnishes the Geological Survey with the final results.

Daily discharge, in second-feet, of Kern River at first point of measurement.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	287	258	863	850	1,615	2,306	1,314	433	201	184	237	269
2	291	268	1,119	893	1,559	2,028	1,269	402	198	190	237	250
3	291	277	1,493	849	1,522	1,811	1,205	373	198	187	241	257
4	290	270	929	831	1,504	1,904	1,090	337	191	183	239	244
5	289	260	756	930	1,520	2,018	989	333	186	172	237	251
6	293	256	772	1,078	1,589	2,215	915	338	186	168	246	269
7	312	251	725	1,647	1,704	2,527	839	328	184	162	249	294
8	314	262	620	3,438	1,765	2,698	766	327	187	167	243	302
9	307	260	717	2,461	1,880	2,701	740	366	186	185	243	296
10	299	263	957	2,000	2,004	2,726	747	374	191	190	269	283
11	287	254	787	1,836	2,065	2,735	736	369	189	185	300	278
12	274	252	770	1,748	2,108	2,642	712	386	195	180	393	314
13	264	254	782	1,752	2,156	2,910	722	385	198	186	340	325
14	274	254	790	1,806	2,135	2,755	711	346	191	190	306	298
15	282	251	723	1,877	1,997	2,400	704	340	206	186	285	272
16	286	259	645	2,008	1,797	2,313	675	330	214	194	273	250
17	286	263	655	2,130	1,827	2,244	631	321	227	195	262	271
18	289	260	728	2,332	1,884	2,195	603	319	223	190	265	299
19	294	268	790	2,620	1,868	2,159	588	307	216	193	281	292
20	292	257	813	2,807	1,697	2,169	550	295	200	195	298	281
21	296	258	758	2,740	1,549	2,159	522	279	198	194	313	267
22	291	279	751	2,306	1,447	2,173	509	278	203	197	298	262
23	281	339	759	2,030	1,403	2,119	505	258	204	200	315	248
24	278	353	794	1,772	1,451	1,887	508	256	198	214	322	237
25	285	379	734	1,682	1,555	1,836	484	254	194	237	310	245
26	272	871	694	1,559	1,673	1,726	466	238	197	262	288	250
27	255	1,252	689	1,505	1,662	1,561	469	224	200	236	292	250
28	247	1,451	667	1,556	1,780	1,410	490	220	179	236	301	253
29	260	.....	681	1,536	2,120	1,431	501	223	176	242	289	258
30	259	.....	735	1,540	2,250	1,296	480	218	179	236	277	242
31	250	.....	779	.....	2,320	.....	460	209	.....	236	.....	245

timated monthly discharge of Kern River at first point of measurement.

[Drainage area 2,345 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
y	321	242	283	17,401	0.12	0.14
ıry	1,828	243	371	20,604	.16	.17
	2,029	601	790	48,575	.34	.39
	3,758	799	1,805	107,405	.77	.86
	2,405	1,375	1,787	109,878	.76	.88
	3,096	1,235	2,165	128,826	.92	1.03
	1,354	453	706	43,410	.30	.35
t	453	205	312	19,184	.13	.15
ıber	232	174	197	11,722	.08	.09
r	292	161	199	12,236	.09	.10
ıber	413	225	281	16,721	.12	.13
ber	346	231	269	16,540	.11	.13
The year	3,758	161	764	552,502	.33	4.42

SAN JOAQUIN RIVER AT HERNDON, CAL.

s station was established in 1879 by the engineering department Southern Pacific Company. The river bed at this point is com- of small gravel and shifting sand. Because of the continual es in the cross section, which were increased by a side channel ing through the gravel pits on the left bank of the river just the gaging station, meter measurements were discontinued at ation at the end of 1901.

river stage record for 1902 has been furnished by William Hood, engineer of the Southern Pacific Company. G. G. Nelson was server.

Daily gage height, in feet, of San Joaquin River at Herndon, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.7	2.5	4.8	4.3	6.0	8.5	5.8	3.5	3.0	2.8	2.6	2.7
2	2.7	2.5	4.5	4.4	6.3	7.5	5.7	3.5	3.0	2.8	2.6	2.7
3	2.7	2.5	5.6	4.2	6.2	7.5	5.5	3.5	3.0	2.8	2.6	2.7
4	2.7	2.5	4.3	4.3	5.7	7.0	5.0	3.5	2.9	2.8	2.6	2.7
5	2.6	2.5	4.0	4.4	5.5	7.3	4.5	3.4	2.9	2.8	2.5	2.7
6	2.6	2.5	3.7	4.5	6.0	7.8	4.3	3.4	2.9	2.7	2.5	2.6
7	2.6	2.5	3.5	6.7	6.5	8.0	4.3	3.4	2.9	2.7	2.5	2.6
8	2.6	2.5	4.0	8.0	6.7	8.5	4.3	3.4	2.8	2.7	2.5	2.6
9	2.6	2.5	4.0	7.0	6.7	9.0	4.1	3.4	2.8	2.7	2.5	2.6
10	2.5	2.5	4.7	6.5	6.8	8.8	4.1	3.8	2.8	2.7	2.5	2.6
11	2.5	2.5	4.3	6.2	7.0	8.5	4.0	3.7	2.8	2.7	4.3	3.3
12	2.5	2.5	4.0	5.7	7.6	9.3	4.5	3.7	2.8	2.7	3.8	4.0
13	2.5	2.5	4.0	5.5	7.8	9.0	4.5	3.6	2.8	2.7	3.7	3.5
14	2.5	2.7	3.8	6.0	7.4	8.5	4.5	3.5	2.8	2.7	3.4	3.3
15	2.5	2.7	3.8	6.2	6.9	8.1	4.6	3.5	2.8	2.6	3.3	3.3
16	2.5	2.6	3.8	6.3	6.4	7.8	4.3	3.5	2.8	2.6	3.2	3.3
17	2.5	2.8	3.7	6.4	6.7	7.5	4.0	3.3	2.8	3.6	3.1	3.3
18	2.5	2.7	3.7	6.5	7.1	7.5	4.0	3.3	2.8	2.6	2.8	3.3
19	2.5	2.8	3.7	7.8	6.6	7.2	4.0	3.3	2.8	2.6	2.8	3.3
20	2.5	2.8	3.8	7.3	6.5	7.1	4.0	3.3	2.8	2.5	2.8	3.3
21	2.5	2.8	3.8	7.0	6.2	7.0	4.0	3.2	2.8	2.5	2.8	3.3
22	2.5	2.8	3.7	6.5	6.0	7.4	4.3	3.2	2.8	2.5	2.8	3.3
23	2.5	3.0	3.7	5.7	6.0	7.0	3.8	3.2	2.8	2.5	2.8	3.2
24	2.5	3.0	3.7	5.5	6.5	7.0	3.8	3.2	2.8	2.5	2.8	3.2
25	2.6	4.5	3.7	5.3	6.8	7.0	3.8	3.2	2.8	2.5	2.8	3.2
26	2.6	5.0	3.7	5.1	7.2	6.8	3.8	3.2	2.8	2.5	2.8	3.2
27	2.6	4.8	3.6	5.0	7.7	6.5	3.7	3.1	2.8	2.8	2.7	3.0
28	2.5	5.0	3.6	5.0	8.3	6.3	3.7	3.1	2.8	2.8	2.7	3.0
29	2.5	.....	3.6	5.0	8.3	6.0	3.6	3.0	2.8	2.7	2.7	3.0
30	2.5	.....	3.6	5.0	8.6	6.0	3.6	3.0	2.8	2.7	2.7	3.0
31	2.5	.....	4.0	.....	8.8	.....	3.6	3.0	.....	2.7	.....	3.0

Miscellaneous measurements in San Francisco Bay drainage basin.

Date.	Stream.	Location.	Gage height.	Discharge.
1902.			*Feet.*	*Sec.-feet.*
Sept. 22	Sacramento	Upper Soda Creek, Castle Crags		15.0
22	do	Upper Bairds station		286.0
24	McCloud	Vanardsdale clubhouse, 1 mile above Squaw Creek.		1,325.0
24	Squaw Creek	Squaw Creek Bridge, Vanardsville road		68.0
		Total McCloud		1,393.0
23	do	Hirze Mountain		1,272.0
26	do	Baird post-office, U. S. fisheries		1,356.0
17	Pit	Bridge above mouth of Fall River		208.0
16	do	Fall River at bridge, Fall River Mills		1,543.0
16	do	Hat Creek at bridge, Carbon post-office		583.0
15	do	At Pecks Bridge		2,350.0
15	do	Burney, ¼ mile below falls		209.0
27	do	Squaw Creek near mouth, Copper City		37.0
27	do	Silverthorn Ferry, Copper City		2,508.0
14	Sacramento	Balls Ferry Bridge		4,455.0

neous measurements in San Francisco Bay drainage basin—Continued.

Stream.	Location.	Gage height.	Discharge.
		Feet.	*Sec.-feet.*
Sacramento	Battle Creek Bridge, near Balls Ferry		313.0
do	Ditch, Battle Creek, Balls Ferry Flour Mills		27.0
	Total Battle Creek		340.0
do	Sacramento	a 7.22	5,848.0
Feather, North Fork	East Branch, Hamilton Bridge, Big Meadows.		163.0
do	Big Spring Branch, 1 mile below boathouse, Big Meadows.		64.0
do	West Branch, ¼ mile below bridge, Bunnell Hotel, Prattville.		327.0
do	Iron bridge near Meadow View Hotel, ¼ mile below junction of east and west branches.		607.0
do	Dotta or Lower Big Spring, near mouth Big Meadows.		109.0
do	Bidwell's sawmill, lower end of Big Meadows.		669.0
do	Butt Valley Creek, near Butt Valley Hotel		27.0
do	Indian Valley at bridge, lower end of valley		22.0
do	Spanish Creek at "Pocket Bridge," lower end of American Valley, near Quincy, Cal.		28.0
do	Huff Bar, Big Bend		595.0
do	Big Bend Tunnel, above Huff Bar		315.0
	Total Big Bend		910.0
do	West Branch, 300 feet above Yankee Hill Bridge.		27.0
Feather, Middle Fork	Above mouth of Nelson Creek		59.0
do	Nelson Creek, just above mouth		33.0
	Total below Nelson Creek		92.0
do	At mouth		215.0
Feather, South Fork	In Little Grass Valley		1.0
do	At Enterprise		1.0
do	Palermo canal at Enterprise		30.0
do	Bidwell Bar		216.0
	Total		246.0
Cache Creek	Yolo Bridge, 5 miles from Woodlands	1.4	56.0
Yuba, North Fork	Bay Counties Power Co.'s flume, below dam		221.0
do	Below Bay Counties Power Co.'s dam		2.0
	Total		223.0
Yuba, Middle Fork	¼ mile below Delhi mine		52.0
do	300 feet below Freemans Bridge		64.0
Yuba, South Fork	North Bloomfield ditch at North Columbia, water from Bowman's reservoir.		7.0
do	Eureka Lake Co.'s ditch, North Columbia, water from French and Faucherie lakes.		9.0
do	Edwards Bridge		59.0
do	Bridgeport Bridge		55.0
do	Excelsior Mining and Irrigation Co.'s canal, Pleasant Valley.		32.0
	Total		87.0
Yuba	Above bridge, 4 miles below Smartsville		487.0

Weather Bureau gage. Highest water mark, 28.6 feet December 27, 1862; lowest water of October 23, 1856.

Miscellaneous measurements in San Francisco Bay drainage basin—Contin

Date.	Stream.	Location.	Gage height.	ch
1902.			*Feet.*	*Se*
Aug. 25	Bear	Below dam of South Yuba Water Co.		
	do	Old mining ditch, ½ mile below Headworks.		
		Total flow mouth of Greenhorn River.		
26	do	Old mining ditch, near Auburn		
25	American, North Fork	200 feet above Iowa Hill road bridge		
25	do	South Yuba Water Co.'s new power canal, ½ mile northwest of Colfax.		
		Total flow near Colfax		
25	do	2½ miles above Auburn		
26	American, Middle Fork.	Rubicon, 300 feet above junction with Middle Fork.		
26	do	300 feet above junction with Rubicon		
26	do	North Fork of, 200 feet above junction with Middle Fork.		
26	do	Mining ditch (takes water from North Fork of Middle Fork).		
		Total flow below junction of Middle Fork.		
25	do	Just above mouth		
25	American, North Fork	Below junction of North and Middle forks		
21	do	Near Mink's place, 5 miles above mouth of South Fork.		
26	do	North Fork canal, near Folsom		
23	do	5 miles above mouth of South Fork, near Mink.	3.7	
27	do	do	3.8	
22	American, South Fork	100 feet above Riverton stone bridge		
22	do	South Fork of Silver Creek, 300 feet above mouth.		
22	do	Silver Creek, 150 feet above junction with South Fork of Silver Creek.		
		Total flow below junction with South Fork.		
23	do	Placerville ditch, 1 mile from Pacific post-office.		
21	do	Chillie Bar Bridge, 3 miles from Placerville.		
21	do	Big Canyon at junction with South Fork		
21	do	At Chillie Bar		
19	do	Natoma ditch, Natoma Vineyard Co.'s lateral.		
19	do	Natoma ditch, Blue Ravine mine		
21	do	Near mouth, 3 miles above Folsom		
22	do	Natoma ditch, below dam at Salmon Falls.		
22	do	Negro Hill canal, below dam at Salmon Falls.		
23	do	2 miles above mouth		
15	Mokelumne, North Fork	½ mile above bridge, near West Point		
15	Mokelumne, Middle Fork	150 feet below bridge, near West Point.		
16	Mokelumne, South Fork	Ditch 2 miles southeast of Fort Mountain, "Big Trees quadrangle."		
15	do	Mokelumne ditch, ½ mile below South Fork Bridge in flume 500 feet below head-gate.		
Aug. 14	Mokelumne	Standard ditch flume No. 59, near Electra		
14	*do*	Amador ditch, in flume 1¼ miles above Electra.		

Miscellaneous measurements in San Francisco Bay drainage basin—Continued.

Date.	Stream.	Location.	Gage height.	Discharge.
1902.			*Feet.*	*Sec.-feet.*
Aug. 14	Mokelumne	500 feet above Standard Electric Co.'s power house, Electra.		51.0
14	do	From Standard power house		30.0
		Total		81.0
13	do	¼ mile below Lancha Plana dam		67.0
15	do	Campo Seco, ¼ mile below old dam		126.0
14	do	Clements at road bridge		65.0
12	do	Bridge at Woodbridge, Cal		33.0
12	do	Woodbridge canal, 100 feet below headworks		40.0
16	do	do		29.0
16	Stanislaus, North Fork	San Antonio Creek, just below mouth of Big Trees Creek.		3.5
17	do	Old Milton (now Angels) ditch, in flume below headworks.		67.0
17	do	Below intake, Angels ditch		1.0
		Total		68.0
17	do	Mill Creek, 30 feet below junction of Love and Moran creeks.		2.0
21	Stanislaus, Middle Fork	Clarks Fork at mouth		53.0
21	do	Below mouth of Clarks Fork		126.0
21	do	Above mouth of Clarks Fork		73.0
20	Stanislaus, South Fork	Canal, Tuolumne Electric Power Co., near intake (takes all of South Fork).		54.0
20	do	Soulsby ditch, branch of Tuolumne Electric Co. canal, 50 feet above main ditch.		16.0
22	Stanislaus	Below Colliers		193.0
21	do	Abbotts Ferry		170.0
23	do	Parrotts Ferry	0.6	168.0
23	do	Robinsons Ferry		158.0
23	do	Ditch near Robinsons Ferry		12.0
		Total		170.0
ay 12	do	Stanislaus Water Co. canal, Flume No. 3		129.0
ug. 17	do	Stanislaus Water Co. canal, below intake		154.0
19	do	¼ mile below Knights Ferry		166.0
20	do	Oakdale, ¼ mile above railroad bridge		125.0
22	Tuolumne, North Fork	In flume of Goldwin Mining Co., all of water of North Fork.		6.0
30	Tuolumne	Cherry Creek, just below Lake Eleanor trail crossing.		6.0
30	do	Eleanor Creek, ¼ mile below trail crossing		4.4
31	Tuolumne, Middle Fork	Below bridge on road from Crockers to Hog ranch.		3.0
29	Tuolumne	Upper end Hetch Hetchy Valley		66.0
29	do	Rancheria Creek, head of falls, ¼ mile southeast of trail.		7.0
29	do	Till-Till Creek, just above junction Rancheria Creek.		0.5
29	do	Falls Creek, 300 feet above junction with Tuolumne.		4.0
29	do	Lower end Hetch Hetchy Valley		89.0
27	do	¼ mile above junction with South Fork		152.0
27	Tuolumne, South Fork	¼ mile above mouth		20.0
ept. 2	Tuolumne	225 feet above falls, lower end Tuolumne Meadows.		23.0
ug. 26	do	Wards Ferry, 300 feet below bridge		159.0

Miscellaneous measurements in San Francisco Bay drainage basin—Continued.

Date.	Stream.	Location.	Gage height.	Discharge.
1902.			*Feet.*	*Sec.-feet.*
Aug. 26	Tuolumne	Jacksonville, at cable crossing		150.0
25	do	Woods Creek, Jacksonville		22.0
27	do	Lagrange ditch and Hydraulic Mining Co. canal above Lagrange dam.		4.0
27	do	Turlock canal, at gate where canal leaves headworks tunnel.		105.0
27	do	Lagrange, 1,000 feet below bridge		15.0
		Total at Lagrange		124.0
Sept. 3	Merced	Illilouette Creek, 100 yards above junction with Merced.		6.0
3	do	150 feet above junction with Illilouette Creek.		33.0
		Total above intake, electric power tunnel, Yosemite Valley.		39.0
3	do	Tenaya, 50 yards above bridge, near camp, Ideal Valley.		2.7
4	do	Bridal Veil Creek, 50 yards below bridge		2.0
4	Merced, South Fork	Below buildings at Wawona		3.2
Aug. 30	Merced, North Fork	At junction		0.0
31	Merced	Bonton Mills power house, in flume		76.0
31	do	Horseshoe Bend, 900 feet below old suspension bridge.		97.0
Sept. 3	do	1 mile above Merced Falls		109.0
1	do	Merced Falls, 1,000 feet below dam		78.0
1	do	Ditch below power house, Merced Falls		15.0
4	do	Crocker Hoffman canal, at road bridge, 3 miles below Snelling.		37.0
6	San Joaquin	Granite Creek, 100 feet below sheep bridge.		0.7
6	do	300 feet below junction with Jackass Creek.		342.0
6	do	Jackass Creek, 50 feet above junction with San Joaquin.		3.0
8	do	Middle Fork, 300 feet above Miller Bridge		148.0
10	Mono Creek	At lowest trail crossing		51.0
10	San Joaquin, South Fork	Trail crossing from Mono to Pine Ridge		107.0
10	Big Creek	Dam site, lower end of valley, trail from Mono to Pine Ridge.		9.0
9	San Joaquin, North Fork	Canal, at reservoir in flume above San Joaquin power house.		18.0
10	San Joaquin	Below San Joaquin electric power house		310.0
8	do	Pollasky, north of pavilion		309.0
11	do	Herndon, at road bridge		323.0
12	do	Below dam, at Mendote		25.0
12	do	Miller and Lux canal, small dam intake No. 3.		260.0
12	do	Miller and Lux canal, at canal bridge No. 2.	5.1	265.0
17	King	Dinkey Creek, 75 feet below old bridge, road Ockenden to Laurel Creek.		3.5
18	King, North Fork	100 yards above trail crossing, 1 mile from Cliff camp.		7.0
18	do	Bear Creek (estimated)		1.5
18	do	Deer Creek (estimated)		1.5
18	do	Blue Canyon Creek		2.0
18	King, Middle Fork	Crown Creek		5.0
20	do	300 feet below trail to Simpsons Meadows		75.0

Miscellaneous measurements in San Francisco Bay drainage basin—Continued.

Date.	Stream.	Location.	Gage height.	Discharge.
1902.			*Feet.*	*Sec.-feet.*
Sept. 22	King, South Fork	Bubbs Creek, 100 yards above junction with South Fork.		32.0
22	do	100 yards below trail, ¼ mile above junction Bubbs Creek.		29.0
		Total below mouth of Bubbs Creek		61.0
22	do	Granite Creek, 50 yards above bridge on trail crossing.		0.7
22	do	Sheep Creek, just above old hotel (estimated).		2.0
23	do	Roaring River, at trail crossing		10.0
22	King, North Fork	¼ mile above mouth		35.0
22	King	Big Creek, just above mouth		0.5
21	do	At Red Mountain gaging station	4.0	217.0
24	do	76 canal, near headworks, Trimmer Springs crossroad.		31.0
22	do	Enterprise canal, Trimmer Springs crossroad.		2.0
24	do	Church canal, Trimmer Springs crossroad.		121.0
24	do	Fowler Switch canal		0.0
24	do	Kingsburg canal, Trimmer Springs crossroad.		5.0
25	do	At bridge, 1 mile north of Reedley		74.0
26	do	Kingsburg, below wagon-road bridge		117.0
25	Kaweah, North Fork	Lower end of Davis ranch		4.0
12	Kaweah, East Fork	Mount Whitney Power Co.'s flume		18.0
27	do	¼ mile above headworks, Mount Whitney Power Co.'s flume.		15.0
27	do	200 feet below junction diversion, Mount Whitney Power Co.'s flume.		15.5
27	Kaweah, Middle Fork	Marble Fork, 100 yards above junction with Middle Fork.		4.0
28	do	100 yards below trail crossing from Soldiers Camp to Tar Gap.		11.0
27	do	100 yards above junction with Marble Fork		20.0
30	do	3 miles above Three Rivers		31.0
10	do	¼ mile above Sequoia National Park line		31.0
26	do	do		29.0
29	Kaweah, South Fork	Horse Creek at lower end of Hackett Meadow.		1.0
25	do	200 yards above bridge on road from Lemon Cove to Three Rivers.		0.7
29	do	Sequoia National Park line, Cahoon's place.		9.8
29	do	Near lower end of sand meadows		2.0
27	Kaweah	¼ mile above iron bridge		33.0
30	Tule, Middle Fork	East Mount Moses near headworks Doyle Power ditch.		2.6
30	do	Above headworks Doyle Power ditch		14.0
30	do	Trail crossing near junction East Fork		24.0
Oct. 1	Tule, East Fork	100 yards above junction with Middle Fork		15.0
		Total below junction of Middle and East forks.		39.0
3	do	Trail crossing from Nelsons to Indian Reservation.		10.0
2	Tule, South Fork	Tom Wheaton's ranch		3.0
2	do	6 miles below Indian Agency, 50 yards above crossroads.		3.0

Miscellaneous measurements in San Francisco Bay drainage basin—Contin

Date.	Stream.	Location.	Gage height.	I ch
1902.			*Feet.*	*Sec*
Oct. 2	Tule, North Fork	At junction with main river		
May 15	Tule, South Fork	Near mouth		
Oct. 2	do	do		
2	Tule	McFarlands Bridge, 8 miles east of Portersville.		
3	do	Pioneer canal intake		
3	do	Pioneer canal, 1 mile below head gate		
3	do	1 mile below intake Pioneer canal, opposite above point.		
3	do	Pioneer canal, Portersville orange grove, no water used for irrigation.		
4	Kern, North Fork	Little Kern, 100 yards above junction with North Fork.		
4	do	100 yards above Little Kern		
		Total		
6	do	Thurston ditch, road crossing to Hot Springs.		
6	do	Upper Murphy ditch, entrance to weir		
6	do	Stafford & Neil ditch at old bridge back of church.		
6	do	Sumner ditch, just above dairy		
6	do	West channel, point diversion, Kern River Power Co.		
6	do	Center channel, point diversion, Kern River Power Co.		
6	do	East channel, point diversion, Kern River Power Co.		
		Total		
7	do	¼ mile above mouth of Salmon, between Salmon and Tobias creeks.		
7	do	Salmon Creek, 50 yards above junction with Kern.		
7	do	¼ mile above gaging station, Kern River Power Co.		
8	do	350 yards below wagon bridge, Isabella to Kernville.		
8	do	Hooper ditch at wagon bridge, Isabella to Kernville.		
8	do	Stafford & Neil ditch, just above flume in gulch.		
8	do	Lower Stafford ditch		
8	Kern South Fork	Above junction with Kern		
8	Kern, North Fork	Lower Murphy ditch, 75 yards above Weldon crossroads.		
8	do	Bennett & Kelley ditch, above Weldon crossroads.		
8	Kern	200 yards below junction, North and South forks.		
8	do	¼ mile above power house, Kern River Power Co.		
8	do	Below Clear Creek		
8	do	Clear Creek at mouth		
7	do	¼ mile below power house at mouth of canyon.		
8	do	"First point of measurement"		
8	do	Democrat Springs at cable Edison Electric Co.		
7	do	Proposed site of Edison power house below intake of company's tunnel.		

SOUTHERN CALIFORNIA DRAINAGE.

Under the head of Southern California drainage have been included data concerning the streams of that part of the State south of the San Joaquin Basin. There are thus included the Mohave, which flows from the mountains north of San Bernardino into the Mohave Desert, a portion of the Great Interior Basin, as well as those flowing toward the south or southwest, whose waters, in times of flood at least, reach the Pacific Ocean.

Arroyo Seco rises on the eastern slope of the Santa Lucia Mountains and flows east and empties into Salinas River at Soledad, Cal.

San Lorenzo Creek drains the western slopes of the Gavilan Mountains and enters Salinas River near King City, Cal. There is a reservoir and dam site 5 miles above its mouth. The flood waters are used for winter irrigation. Salinas River drains into the Pacific through Monterey Bay.

The drainage basin of San Gabriel River lies on the southern slope of the Sierra Madre, being included in Los Angeles County, Cal. The various tributaries join the river before it enters its lowest canyon, whence it appears finally on the plain in the vicinity of Azusa. The seepage waters of this valley appear lower down in the river and finally enter the Pacific Ocean not far from the mouth of Los Angeles River. All of the surplus waters of this stream are now used for irrigation purposes, and it is only an occasional flood that passes the gaging station.

Santa Ana River has its source on the southern slope of the San Bernardino Mountains and flows southerly, appearing from its canyon 4 miles north of Redlands. Its waters are completely used in San Bernardino Valley. At the lower part of the valley the water appears again in the vicinity of Rincon where the river passes through a comparatively narrow gorge, and the general direction of the stream is thence southwesterly, emptying into the Pacific Ocean.

The headwaters of Mohave River have their source on the northern slope of the Sierra Madre. It flows north, finally disappearing in the sands of the Mohave Desert.

The following is a list of the stations in the Southern California drainage:

Arroyo Seco at Pettitt's ranch, near Soledad, Monterey County, Cal.
San Lorenzo Creek near King City, Cal.
San Gabriel River and canals at Azusa, Cal.
Santa Ana River below Warmsprings, Cal.
Mohave River at Victorville, Cal.

ARROYO SECO AT PETTITT'S RANCH, NEAR SOLEDAD, MONTEREY COUNTY, CAL.

A gaging station was established by W. W. Cockins, jr., December, 1900, at Foster's ranch, near Piney post-office, California. The high water of January, 1901, enlarged an old channel, and the gaging station was removed to Pettitt's ranch, 4 miles below. The purpose of establishing these gaging stations was to get the maximum flood discharge and the amount of water available for storage. The total are

of the basin drained above Pettitt's ranch is 215 square miles. The observer is Mrs. Charles Pettitt.

Discharge measurements of Arroyo Seco at Pettitt's ranch near Soledad, Monterey County, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
February 24	S. G. Bennett	8.2	1,720
February 25	do	11.7	7,883
February 26	do	9.0	2,777
April 29	do	5.75	144
July 18	H. Hamlin	5.08	10
August 7	do	4.9	2
November 14	do	5.42	50
November 15	do	5.40	35
December 31	S. G. Bennett	5.40	43

Daily gage height, in feet, of Arroyo Seco at Pettitt's ranch near Soledad, Monterey County, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	5.3	5.3	7.5	5.9	5.7	5.5	5.2	5.0	4.9	4.8	5.2	5.3
2	5.3	5.3	8.7	6.0	5.7	5.4	5.2	5.0	4.9	4.8	5.2	5.3
3	5.3	5.3	7.8	5.9	5.7	5.5	5.2	5.0	4.8	4.8	5.2	5.3
4	5.3	5.3	7.2	5.8	5.7	5.4	5.2	4.9	4.9	4.8	5.2	5.3
5	5.3	5.3	6.9	5.8	5.7	5.4	5.2	5.0	4.8	4.9	5.2	5.3
6	5.3	5.3	7.1	5.8	5.7	5.4	5.2	4.9	4.9	4.8	5.1	5.3
7	5.3	5.3	6.9	8.1	5.7	5.4	5.2	4.9	4.8	4.9	5.1	5.3
8	5.3	5.3	8.3	6.7	5.6	5.4	5.2	4.9	4.8	4.9	5.1	5.3
9	5.3	5.7	7.9	6.4	5.7	5.4	5.2	4.9	4.8	4.9	5.1	5.4
10	5.3	5.5	7.3	6.3	5.6	5.4	5.2	4.9	4.8	4.9	7.0	5.8
11	5.3	5.5	7.1	6.2	5.6	5.4	5.2	4.9	4.8	4.9	5.9	5.7
12	5.3	5.6	6.8	6.2	5.6	5.4	5.2	4.9	4.8	4.9	5.5	5.7
13	5.3	5.5	6.8	6.1	5.6	5.4	5.2	4.9	4.8	5.0	5.5	5.7
14	5.3	5.5	6.5	6.0	5.6	5.4	5.1	4.9	4.8	4.9	5.4	5.6
15	5.3	6.4	6.4	6.0	5.6	5.4	5.1	4.9	4.8	5.0	5.4	5.5
16	5.3	6.0	6.3	6.0	5.6	5.3	5.1	4.9	4.8	4.9	5.4	5.7
17	5.3	6.0	6.3	6.0	5.6	5.3	5.1	4.9	4.8	5.0	5.4	5.6
18	5.3	5.9	6.2	5.9	5.6	5.3	5.1	4.9	4.8	4.9	5.4	5.5
19	5.3	5.9	6.2	5.9	5.5	5.3	5.1	4.9	4.8	5.0	5.4	5.5
20	5.4	5.7	6.2	5.9	5.5	5.3	5.1	4.9	4.8	5.0	5.4	5.5
21	5.3	7.4	6.1	5.9	5.5	5.3	5.1	4.9	4.8	5.0	5.4	5.5
22	5.3	8.8	6.0	5.9	5.5	5.3	5.1	4.9	4.8	5.0	5.3	5.5
23	5.3	6.3	6.0	5.8	5.5	5.3	5.0	4.9	4.8	5.0	5.3	5.4
24	5.3	8.7	6.1	6.0	5.5	5.3	5.0	4.9	4.8	5.3	5.3	5.5
25	5.4	9.1	6.0	5.9	5.5	5.3	5.0	4.9	4.8	5.5	5.3	5.4
26	5.4	9.1	6.1	5.9	5.5	5.2	5.0	4.9	4.8	5.4	5.3	5.4
27	5.4	8.2	6.0	5.8	5.5	5.2	5.0	4.9	4.8	5.2	5.3	5.5
28	5.4	7.8	5.9	5.8	5.5	5.2	5.0	4.9	4.8	5.2	5.3	5.4
29	5.4	.....	5.9	5.8	5.5	5.2	5.0	4.9	4.8	5.2	5.3	5.4
30	5.3	.....	5.9	5.8	5.5	5.2	5.0	4.9	4.8	5.2	5.3	5.4
31	5.3	.....	5.9	.....	5.5	.....	5.0	4.9	.....	5.2	.....	5.4

Rating table for Arroyo Seco River at Pettitt's ranch near Soledad, Monterey County, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
5.0	7	6.8	620	8.6	2,200	10.4	5,130
5.2	15	7.0	750	8.8	2,450	10.6	5,540
5.4	40	7.2	890	9.0	2,720	10.8	5,960
5.6	75	7.4	1,030	9.2	3,010	11.0	6,380
5.8	145	7.6	1,190	9.4	3,320	11.2	6,800
6.0	230	7.8	1,360	9.6	3,650	11.4	7,220
6.2	320	8.0	1,550	9.8	4,000	11.6	7,650
6.4	410	8.2	1,750	10.0	4,360	11.8	8,090
6.6	510	8.4	1,970	10.2	4,740	12.0	8,530

Estimated monthly discharge of Arroyo Seco at Pettitt's ranch near Soledad, Monterey County, Cal.

[Drainage area, 215 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	40	25	28	1,722	0.13	0.15
February	2,860	25	605	33,600	2.81	2.93
March	2,320	185	620	38,122	2.88	3.32
April	1,650	145	270	16,066	1.26	1.41
May	105	55	74	4,550	.34	.39
June	55	15	32	1,904	.15	.17
July	15	7	12	738	.06	.07
August	7	3	4	246	.02	.02
September	3	0	0	0	.00	.00
October	55	0	9	553	.04	.05
November	750	11	57	3,392	.27	.30
December	145	25	54	3,320	.25	.29
The year	2,860	0	147	104,213	.68	9.10

SAN LORENZO CREEK NEAR KING CITY, CAL.

A gaging station was established December 16, 1900, at Hollenbeck's ranch. To obtain a reliable observer it was necessary to move the gaging station to the Mathews dam site one-half mile above the Hollenbeck ranch on November, 1901. The stream is very flashy, and the rating curve for 1902 was completed by taking the cross section and slope with a level and calculating the discharge by the Kutters formula. The observer is J. L. Mathews.

Discharge measurements of San Lorenzo Creek near King City, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
January 24	S. G. Bennett	0.9	5
February 24	do	1.09	43
April 30	do	.09	2
July 16	H. Hamlin		1
November 12	do	.85	6

Daily gage height, in feet, of San Lorenzo Creek near King City, Cal.

Day.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.
1902.							
1	0.9	0.9	1.1	0.9		1.0	1.0
2	.9	.9	3.0	.9		1.0	1.0
3	.9	.9	2.2	.9		1.0	.9
4	.9	.9	1.4	.9		1.0	.9
5	.9	.9	1.2	.9		1.0	.9
6	.9	.9	1.6	.9		1.0	.9
7	.9	.9	1.6	.9		1.0	.9
8	.9	.9	1.8	.9		1.0	.9
9	.9	.9	1.8	.9		1.0	.9
10	.9	.9	1.6	.9		1.0	1.0
11	.9	.9	1.2	.9		1.8	1.0
12	.9	.9	1.2	.9		1.7	1.0
13	.9	.9	1.1	.9		1.6	1.0
14	.9	.9	1.0	.9		1.6	.9
15	.9	.9	1.0	.9		1.6	.9
16	.9	.9	1.0	.9		1.6	.9
17	.9	.9	1.0	.8		1.6	.9
18	.9	.9	1.0	.8		1.5	.9
19	.9	.9	1.0	.8	0.9	1.8	.9
20	.9	.9	1.0	.8	.9	1.7	.9
21	.9	.9	.9	.8	1.0	1.6	.9
22	.9	1.7	.9	.8	1.0	1.6	.9
23	.9	1.6	.9	.8	1.0	1.4	.9
24	1.0	1.7	.9	.8	1.0	1.4	.9
25	1.0	2.9	1.0	.8	1.0	1.4	.9
26	.9	2.3	1.0	.8	1.0	1.4	.9
27	.9	1.5	.9	.9	1.0	1.4	.9
28	.9	1.2	.9	.9	1.0	1.4	.9
29	.9		.9	.9	1.0	1.2	.9
30	.9		.9	.9	1.0	1.2	.9
31	.9		.9		1.0		[illegible]

Rating table for San Lorenzo Creek near King City, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.8	3	1.4	88	2.0	274	2.6	585
.9	5	1.5	110	2.1	317	2.7	650
1.0	15	1.6	135	2.2	364	2.8	720
1.1	32	1.7	166	2.3	415	2.9	795
1.2	50	1.8	200	2.4	470	3.0	875
1.3	68	1.9	236	2.5	525		

Estimated monthly discharge of San Lorenzo Creek near King City, Cal.

[Drainage area, 235 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	15	5	6	369	0.03	0.03
February	795	5	69	3,832	.29	.30
March	875	5	81	4,980	.34	.39
April	5	3	4	238	.02	.02
October 19–31	----------	----------	15	357	.06	.03
November	200	15	85	5,057	.36	.40
December	15	5	7	430	.03	.03

SAN GABRIEL RIVER AND CANALS AT AZUSA, CAL.

Owing to the numerous diversions it has been difficult to obtain accurate discharge measurements at Azusa; but during 1898 the San Gabriel Electric Company completed its system, and measurements are now obtained with greater ease and hence with greater accuracy. The headworks of this company are located about 6 miles above the mouth of the canyon; the water is carried along the left side by a series of tunnels and conduits, and a head of 400 feet is obtained where the electric power is generated. Weirs are placed on the conduit of the electric company, and the water is measured at this point. The capacity of the conduit is 90 second-feet.

The total flow of the river is obtained by adding the daily discharge for the river to the figures for the corresponding dates for the canals. The observer is H. F. Parkinson.

Discharge measurements of San Gabriel River at Azusa, Cal.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1902.		*Feet.*	*Second-feet.*	
April 8	S. G. Bennett	1.4	26.0	
			34.0	Over weirs San Gabriel Power Company Canal.
			11.0	Waste gate San Gabriel Power Company.
			71.0	Total flow of San Gabriel River.
June 12	do		25.7	Flow over weirs of San Gabriel Power Company=total flow of river.
September 1	W. B. Clapp		5.0	Do.

Daily gage height, in feet, of San Gabriel River at Azusa, Cal.

Day.	Feb.	Mar.	Apr.	Nov.	Day.	Feb.	Mar.	Apr.	Nov.
1902.					1902.				
1	(a)	0.85	1.10		17		1.00	0.00	
2		3.00	1.50		18		.93	0.00	
3		1.90	1.10		19		1.25	0.00	
4		1.55	1.05		20		1.05	0.00	
5		1.40	1.02		21		.90	1.05	
6		1.57	1.00		22		.80	0.80	
7		1.20	1.20		23		.90	0.00	
8		1.20	1.20		24		1.65	0.00	
9		2.30	1.15		25		1.40	0.00	
10		1.95	1.10		26	1.75	1.30	0.00	
11		1.70	1.05	1.20	27	1.35	1.15	0.00	
12		1.50	1.00	(a)	28	1.05	1.10	0.00	
13		1.40	1.00		29		1.05	0.00	
14		1.30	0.95		30		1.20	0.00	
15		1.20	0.00		31		1.10		
16		1.10	0.00						

a River dry January 1 to February 25, May 1 to November 10, and November 12 to December 31.

Daily discharge, in second-feet, of San Gabriel canals at Azusa.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	25	30	58	62	48	30	16	7	5	6	9	16
.....	25	30	60	62	48	28	16	7	5	6	8	16
.....	25	30	60	62	48	26	16	8	5	6	8	16
.....	25	30	60	62	47	26	17	7	5	6	8	16
.....	25	30	61	62	46	25	17	8	5	6	8	17
.....	25	29	62	62	46	23	16	8	5	6	8	17
.....	25	29	62	62	46	21	16	7	5	6	8	18
.....	25	29	62	62	45	20	14	7	4	6	9	18
.....	25	29	62	62	43	20	12	8	5	6	9	24
.....	25	29	62	62	43	22	12	8	5	6	9	30
.....	25	29	62	62	43	25	11	8	5	7	62	36
.....	24	29	62	62	42	25	10	8	5	8	43	32
.....	24	28	62	46	40	22	10	8	5	8	25	28
.....	24	28	62	62	44	22	10	8	5	8	23	26
.....	24	28	62	62	42	21	10	8	5	6	23	25
.....	24	28	62	62	40	20	10	8	6	6	23	25
.....	24	28	62	62	40	20	10	8	6	6	22	46
.....	27	28	62	60	37	19	10	8	6	6	22	68
.....	30	27	62	61	37	18	10	8	6	6	22	61
.....	28	27	62	61	37	16	8	8	6	7	22	55
.....	26	32	62	62	37	16	8	7	6	7	21	48
.....	26	38	62	62	36	16	8	6	6	8	20	42
.....	26	34	62	60	35	14	8	6	6	9	20	35
.....	51	35	62	60	34	14	8	7	6	10	20	35
.....	42	40	62	56	34	14	8	6	6	10	20	35
.....	32	63	62	54	34	14	9	6	6	9	20	35
.....	32	62	62	52	32	14	10	6	6	8	20	35
.....	32	62	62	50	30	15	10	6	6	8	20	34
.....	32	.....	62	48	30	15	10	6	6	8	19	33
.....	31	.....	55	48	30	14	9	6	6	8	17	32
.....	30	.....	62	.....	30	.....	8	6	.....	8	.....	31

Rating table for San Gabriel River at Azusa, Cal., for 1902.

Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Second-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4	1.5	37	2.2	128	2.9	288
7	1.6	44	2.3	147	3.0	318
10	1.7	52	2.4	167	3.1	350
13	1.8	63	2.5	188	3.2	384
18	1.9	77	2.6	210		
24	2.0	93	2.7	234		
30	2.1	110	2.8	260		

Estimated monthly discharge of San Gabriel River at Azusa, Cal.

[Drainage area, 222 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	0	0	0	0
February	57	0	3	167
March	318	4	38	2,337
April	37	0	7	417
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	18	0	0	0
December	0	0	0	0
The year	318	0	4	2,921

Estimated monthly discharge of San Gabriel canals at Azusa, Cal.

[Drainage area 222 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
1902.				
January	51	24	28	1,722
February	63	27	34	1,888
March	62	55	61	3,751
April	62	46	59	3,511
May	48	30	39	2,398
June	30	14	20	1,190
July	17	8	11	676
August	8	6	7	430
September	6	4	5	298
October	10	6	7	430
November	62	8	19	1,131
December	68	16	32	1,968
The year	68	4	27	19,393

ıated monthly discharge of San Gabriel River and canals at Azusa, Cal.

[Drainage area 222 square miles.]

Month	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
.....	51	24	28	1,722	0.13	0.15
y	120	38	37	2,055	.17	.18
.....	378	63	99	6,088	.45	.52
.....	99	48	66	3,928	.30	.33
.....	48	30	39	2,398	.18	.21
.....	30	14	20	1,190	.09	.10
.....	17	8	11	676	.05	.06
.....	8	6	7	430	.03	.03
ber	6	4	5	298	.02	.02
.....	10	6	7	430	.03	.03
ber	80	8	19	1,131	.09	.10
er	68	16	32	1,968	.14	.16
he year	378	4	31	22,314	.14	1.89

SANTA ANA RIVER BELOW WARMSPRINGS, CAL.

station, established June, 1896, is located 5 miles northeast of ıe, Cal., three-fourths of a mile below the head works of the Ana canal and opposite the warm springs in the canyon. The an inclined timber fastened to a large bowlder and posts set bank of the river. The observer is A. Larrd.

ıg to the shifting nature of the stream bed it has not been pos-) construct perfectly satisfactory rating curves, but the tables ented are based on the best information that could be obtained. ecord is not considered absolutely correct, but is given as an imation. This river is one of the most difficult streams in the f which to obtain an accurate record. The Edison Electric ıny diverts the greater portion of the water of Santa Ana River the gaging station, but also returns all of it above the station. however, allow only limited portions of the water to pass out of onduits during certain hours of the day, holding back the water purpose of obtaining additional power when the greatest demand

The Santa Ana canal, as mentioned above, also diverts water anta Ana River above the station, all of which is returned to ınnel of the stream after passing the point of measurement.

During the greater part of the year the canals at the mouth o canyon divert all of the water. At such times the discharge of S Ana River was obtained by observations on weirs at the head w of Green Spot pipe line, Highlands canal, and Redlands canal. water entering Redlands canal from the Redlands tunnel and Mc Canyon was assumed to offset the loss by evaporation and see between the old gaging station and the mouth of the canyon.

Discharge measurements of Santa Ana River and canal at Warmsprings

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1902.		*Feet.*	*Second-feet.*	
April 5	S. G. Bennett	1.39	51	River.
		--------	4	Santa Ana Canal.
		--------	55	Total discharge f drainage basin.
May 31	do	.91	8	River.
		--------	21	Santa Ana Canal.
		--------	29	Total flow.
July 10	do	.84	5	River.
		--------	18	Santa Ana Canal.
		--------	23	Total.
September 3	W. B. Clapp	.95	10	River.
		--------	14	Santa Ana Canal.
		--------	24	Total.
November 5	S. G. Bennett	.87	5	River.
		--------	13	Santa Ana Canal.
		--------	18	Total.

ge height, in feet, and discharge, in second-feet, of Santa Ana River and canal[a] at Warmsprings, Cal.

	Jan.		Feb.		Mar.		Apr.		May.		June.	
	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.	Gage height.	Dis-charge.
		20		20	1.50	63	1.35	42		45		32
		22		24	2.80	485	1.40	48		44		30
		24		22	1.60	80	1.40	48		43		29
		23		25	1.50	63	1.40	48		43		30
		23		27	1.50	63	1.45	56		42		27
		23		28	1.25	31	1.33	40		40		29
		21		27	1.45	56	1.35	42		39		26
		23		27	1.36	43	1.38	46		40		26
		23		27	2.03	187	1.30	36		38		26
		22		27	1.70	102	1.30	36		38		32
		23		28	1.55	72	1.27	33		37		34
		23		28	1.55	72	1.27	33		34		40
		23		28	1.55	72	1.25	31		34		39
		23		27	1.55	72	1.24	30		38		39
		23		28	1.35	42	1.24	30		34		47
		23		28	1.23	29	1.24	30		35		45
		23		28	1.25	31	1.23	29		35		45
		23		28	1.25	31	1.23	29		35		45
		23		27	1.30	36	1.24	30		35		44
		24		26	1.25	31	1.25	31		33		29
		22		26	1.22	28	1.45	56		33		27
		24		32	1.25	31	1.30	36		32		27
		24		33	1.30	36	1.31	37		33		26
		45		30	1.40	48		54		33		39
		41		33	1.45	56		49		32		35
		28	2.20	240	1.50	63		47		34		30
		25	1.60	80	1.55	72		46		31		32
		26	1.50	63	1.53	68		43		31		31
		25			1.53	68		46		31		23
		21			1.50	63		44		31		23
		21			1.45	56				31		

rge of river was obtained by measurements over weirs on days when gage heights are

Daily gage height, in feet, and discharge, in second-feet, of Santa Ana River[a] canal at Warmsprings, Cal.—Continued.

Day.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Dis-
1902.												
1		24		24		23		31		43		
2		32		24		25		30		23		
3		31		25		26		31		23		
4		31		25		29		33		22		
5		23		25		26		37		20		
6		23		25		24		36		19		
7		23		26		23		34		20		
8		25		28		23		37		20		
9		25		30		23		42		20		
10		25		29		24		43		20		
11		23		28		25		44		31		
12		26		28		23		42		26		
13		26		28		28		36		23		
14		27		25		27		36		23		
15		26		25		24		35		23		
16		24		25		23		33		23		
17		24		25		24		32		19		
18		25		25		24		32		20		
19		24		24		25		34		31		
20		24		23		26		36		25		
21		24		22		26		40		23		
22		24		22		24		39		24		
23		25		22		23		49		24		
24		25		22		23		51		21		
25		28		23		22		55		23		
26		26		25		22		27		26		
27		25		22		23		49		26		
28		30		25		23		50		26		
29		30		26		25		47		26		
30		27		27		27		49		26		
31		26		26				52				

[a] Discharge of river was obtained by measurements over weirs on days when gage heights a not given.

Daily mean discharge, in second-feet, of Santa Ana canal[a] below Warmspring Cal.

Day.	Feb.	Mar.	Apr.	Day.	Feb.	Mar.	Apr.	Day.	Feb.	Mar.	Ap
1902.				1902.				1902.			
1		12	11	12		0	15	23		14	
2		0	15	13		13	15	24		0	
3		0	15	14		15	15	25		0	
4		0	15	15		15	15	26	0	0	
5		12	15	16		13	15	27	0	0	
6		11	15	17		14	14	28	0	0	
7		0	15	18		14	14	29		0	
8		0	15	19		14	13	30		0	
9		0	15	20		14	13	31			
10		0	15	21		13	13				
11		0	15	22		14	13				

[a] On days not given in above table there was no discharge.

Rating table for Santa Ana River below Warmsprings, Cal., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	12	1.6	80	2.2	240	2.8	485
1.1	18	1.7	102	2.3	277	2.9	540
1.2	26	1.8	125	2.4	315	3.0	600
1.3	36	1.9	150	2.5	355		
1.4	48	2.0	178	2.6	395		
1.5	63	2.1	208	2.7	440		

timated monthly discharge at Santa Ana River and canal below Warmsprings, Cal.

[Drainage area, 182 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	45	20	24	1,476	0.13	0.15
ebruary	240	20	38	2,110	.21	.22
larch	485	41	79	4,858	.43	.50
pril	71	43	51	3,035	.28	.31
lay	45	31	36	2,214	.20	.23
une	47	23	33	1,964	.18	.20
uly	32	23	26	1,599	.14	.16
ugust	30	22	25	1,537	.14	.16
eptember	29	22	24	1,428	.13	.15
ctober	55	30	39	2,398	.21	.24
ovember	43	19	24	1,428	.13	.15
ecember	27	19	22	1,353	.12	.14
The year	485	19	35	25,400	.19	2.61

he above discharges include the discharges given in a separate table of Santa Ana Canal.

MOHAVE RIVER AT VICTORVILLE, CAL.

At Victorville, a station on the Atchison, Topeka and Santa Fe Raild, the river passes through a narrow gorge, locally known as The rrows. This place has been under investigation as a possible dam , and soundings for the depth of bed rock were made by the ited States Geological Survey during the season of 1899. The *atest depth of bed rock* was found to be 54 feet. The diamond

drill showed the rock to be a fine granite. A more detailed account of this exploration will be found in the Twenty-first Annual Report, Part IV. Above The Narrows the valley broadens into a large reservoir site, but as no surveys of it have been made the capacity is unknown. In order to determine the amount of water available for storage for this reservoir a gaging station was established February 27, 1899.

During 1902 no flood passed the gaging station. The channel is in sand, which is constantly shifting. The rod readings are of little value during low stages. Between January 1, 1902, and May 3, 1902, the discharge varied from 47 to 67 cubic feet per second, though the gage reading was 0.9 for the entire time. At the latter date the rod readings were discontinued.

The mean estimated discharge for each month was obtained by averaging the discharge as obtained by meter measurements made during the month.

Discharge measurements of Mohave River at Victorville, Cal.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
January 4	P. H. Leahy	0.9	47
January 21	do	.9	53
February 1	do	.9	58
February 25	do	.9	63
March 5	do	.9	66
March 29	do	.9	66
April 5	do	.9	67
April 19	do	.9	62
April 26	do	.9	47
May 10	do	.9	37
May 25	do		49
June 8	do		53
June 27	do		47
July 5	do		38
July 26	do		41
August 9	do		48
August 15	do		33
October 20	do		49
October 30	do		45
November 10	do		43
November 27	do		50
December 11	do		68
December 19	do		69
December 27	S. G. Bennett		55

Estimated monthly discharge of Mohave River at Victorville, Cal.

[Drainage area, 400 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
y	53	47	50	3,074	0.13	0.15
ry	63	58	60	3,332	.15	.16
	66	66	66	4,058	.17	.20
	67	47	59	3,512	.15	.17
	49	37	43	2,644	.11	.13
	53	47	50	2,975	.13	.15
	41	38	40	2,460	.10	.12
	48	33	40	2,460	.10	.12
ıber [a]			44	2,618	.11	.12
r	49	45	47	2,890	.12	.14
ber	50	43	46	2,737	.12	.13
ber	69	55	64	3,808	.16	.18
The year	69	33	51	36,568	.13	1.77

[a] Estimated.

ISCELLANEOUS MEASUREMENTS IN SOUTHERN CALIFORNIA DRAINAGE.

Ventura River.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
		Feet.	*Sec.-feet.*	
ber 25	J. B. Lippincott		2.0	Matilija, above mouth of North Fork.
ber 25	do		5.23	Below diversion of Ventura City water system, Cayote Creek.
ber 26	do		1.5	Power ditch near head.

Ventura River, North Fork.

ber 25	J. B. Lippincott		0.33	In flume.

San Gabriel River.

ber 1	W. B. Clapp		0.9	Slauson well.
	J. B. Lippincott		16.5	Banta ditch, near head.
	do		10.6	Cate ditch.
	do		19.1	Standifer ditch.
	do		23.8	San Gabriel River (Rio Hondo), Old Mission Bridge.

Discharge measurements of San Gabriel River at Azusa, Cal.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1902.		*Feet.*	*Second-feet.*	
April 8	S. G. Bennett	1.4	26.0	
			34.0	Over weirs San Gabriel Power Company Canal.
			11.0	Waste gate San Gabriel Power Company.
			71.0	Total flow of San Gabriel River.
June 12	do		25.7	Flow over weirs of San Gabriel Power Company=total flow of river.
September 1	W. B. Clapp		5.0	Do.

Daily gage height, in feet, of San Gabriel River at Azusa, Cal.

Day.	Feb.	Mar.	Apr.	Nov.	Day.	Feb.	Mar.	Apr.	Nov.
1902.					1902.				
1	(a)	0.85	1.10		17		1.00	0.00	
2		3.00	1.50		18		.93	0.00	
3		1.90	1.10		19		1.25	0.00	
4		1.55	1.05		20		1.05	0.00	
5		1.40	1.02		21		.90	1.05	
6		1.57	1.00		22		.80	0.80	
7		1.20	1.20		23		.90	0.00	
8		1.20	1.20		24		1.65	0.00	
9		2.30	1.15		25		1.40	0.00	
10		1.95	1.10		26	1.75	1.30	0.00	
11		1.70	1.05	1.20	27	1.35	1.15	0.00	
12		1.50	1.00	(a)	28	1.05	1.10	0.00	
13		1.40	1.00		29		1.05	0.00	
14		1.30	0.95		30		1.20	0.00	
15		1.20	0.00		31		1.10		
16		1.10	0.00						

a River dry January 1 to February 25, May 1 to November 10, and November 12 to December 31.

Daily discharge, in second-feet, of San Gabriel canals at Azusa.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	25	30	58	62	48	30	16	7	5	6	9	16
.....	25	30	60	62	48	28	16	7	5	6	8	16
.....	25	30	60	62	48	26	16	8	5	6	8	16
.....	25	30	60	62	47	26	17	7	5	6	8	16
.....	25	30	61	62	46	25	17	8	5	6	8	17
.....	25	29	62	62	46	23	16	8	5	6	8	17
.....	25	29	62	62	46	21	16	7	5	6	8	18
.....	25	29	62	62	45	20	14	7	4	6	9	18
.....	25	29	62	62	43	20	12	8	5	6	9	24
.....	25	29	62	62	43	22	12	8	5	6	9	30
.....	25	29	62	62	43	25	11	8	5	7	62	36
.....	24	29	62	62	42	25	10	8	5	8	43	32
.....	24	28	62	46	40	22	10	8	5	8	25	28
.....	24	28	62	62	44	22	10	8	5	8	23	26
.....	24	28	62	62	42	21	10	8	5	6	23	25
.....	24	28	62	62	40	20	10	8	6	6	23	25
.....	24	28	62	62	40	20	10	8	6	6	22	46
.....	27	28	62	60	37	19	10	8	6	6	22	68
.....	30	27	62	61	37	18	10	8	6	6	22	61
.....	28	27	62	61	37	16	8	8	6	7	22	55
.....	26	32	62	62	37	16	8	7	6	7	21	48
.....	26	38	62	62	36	16	8	6	6	8	20	42
.....	26	34	62	60	35	14	8	6	6	9	20	35
.....	51	35	62	60	34	14	8	7	6	10	20	35
.....	42	40	62	56	34	14	8	6	6	10	20	35
.....	32	63	62	54	34	14	9	6	6	9	20	35
.....	32	62	62	52	32	14	10	6	6	8	20	35
.....	32	62	62	50	30	15	10	6	6	8	20	34
.....	32	.....	62	48	30	15	10	6	6	8	19	33
.....	31	.....	55	48	30	14	9	6	6	8	17	32
.....	30	.....	62	.....	30	.....	8	6	.....	8	.....	31

Rating table for San Gabriel River at Azusa, Cal., for 1902.

ge ht.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
t.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
.8	4	1.5	37	2.2	128	2.9	288
9	7	1.6	44	2.3	147	3.0	318
.0	10	1.7	52	2.4	167	3.1	350
.1	13	1.8	63	2.5	188	3.2	384
.2	18	1.9	77	2.6	210		
.3	24	2.0	93	2.7	234		
.4	30	2.1	110	2.8	260		

Santa Ana River—Continued.

MILL CREEK.

Date.	Hydrographer.	Gage height.	Discharge.	Remarks.
1902.		*Feet.*	*Sec.-feet.*	
April 5	S. G. Bennett		11.0	Old zanja.
			5.0	Wash.
			5.0	Crafton canal.
			21.0	Total.
May 31	S. G. Bennett		19.0	Total flow.
July 10	do		10.8	Crafton weir, total flow
September 3	W. B. Clapp		5.3	Total flow.
November 5	S. G. Bennett		12.3	Old zanja, total flow.

Return water to Santa Ana River, natural flow in second-feet, compared w developed water in San Bernardino Valley, above Colton.

[Measurements by K. Sanborn.]

Date.	Location.	Discharge.		
		Developed.	Natural.	To
1902.				
September 30	Hawes & Talmage ditch		0.00	
September 30	Rabel dam		0.00	
September 30	Shay or Stout dam		0.00	
September 30	McKinzie		0.00	
October 13	Beam		0.22	
September 30	Riverside Water Co.'s upper canal	26.08	21.89	
October 7	Gage canal, intake Santa Ana River		0.00	
October 11	Gage canal, flume over road Redlands Pass	30.17		
October 13	Logsdon & Farrell		0.00	
October 13	Whitlock		0.00	
October 13	Daley		0.00	
October 7	McIntyre		0.00	
October 13	Whiting		0.00	
October 14	Swamp		0.93	
October 7	Ranchero & Bloomington	2.28		
October 14	Ward & Warren	0.30	1.58	
September 30	Mill flume, Riverside Water Co		0.50	
September 30	Mill pump, Riverside Water Co	1.20		
October 7	Camp Carlton	1.70		
October 7	Colton Terrace Water Co	1.08		
October 7	City of Colton pumping plant	3.53		
September 30	Meeks & Daley ditch		13.40	
September 29	West Riverside 350-inch pumping plant	5.94		
October 11	Rogers pumping plant	4.38		
October 11	Santa Ana River flume, Riverside pumping plant No. 1	2.95		
October 11	Santa Ana River flume, Riverside pumping plant No. 2	2.08		
	Total	81.69	38.52	1

NOTE.—The West Riverside flume carries the water pumped by the West Riverside 350 plant, a portion of the water pumped by the Rogers pumping plant, and also a portion o Meeks & Daley water; for these reasons it is not included under a special heading.

The Gage canal, Palm Avenue weir, and Bloomington flume torn out. Bloomington w *running in the Ranchero* ditch.

East Riverside Irrigation District or the Riverside Highland Water Co. running 2.7 second *over weir in tunnel*, and pumping direct into the main pipe below end of tunnel, one pum *plant not running.*

Return waters in San Bernardino Valley below Slover Mountain and above Riverside Narrows, Santa Ana.

[K. Sanborn, hydrographer.]

Date.	Location.	Discharge.
		Sec.-feet.
September 3	Santa Ana River, at Rincon wagon bridge	[a]75.00
September 29	Riverside Water Co. flume, at head of lower canal	3.07
September 29	Rubidoux canal	7.19
September 29	Evans ditch, at north line, Riverside canal	2.17
September 29	Evans ditch, 1 mile south of Riverside canal line	0.53
September 29	Evans Island ditch, at west end of West Riverside bridge	5.35
September 29	Alvetriz ditch, at east end of West Riverside bridge	1.96
October 10	Santa Ana River, at Riverside Narrows	43.25
	Total	63.52

[a] W. B. Clapp.

COLUMBIA RIVER DRAINAGE BASIN.

Next to the Colorado, Columbia River is the largest river in the arid region, its drainage basin including parts of Washington, Oregon, Idaho, and Montana and a large area in Canada. The Columbia and its numerous tributaries are of great importance, offering good sites for water-power development and an abundance of water for irrigation, while the main river is navigable for a considerable distance.

A great part of the water of Columbia River and its tributaries flows to waste, not being utilized. This is due to the fact that the river has cut so deeply into the lava-covered plains that water can not be diverted except at points near the mountains, where the streams are of small size and have not yet entered the deeply incised canyon in the plateaus. The following rivers are tributary to the Columbia:

Umatilla River rises in the well-wooded country in northeastern Oregon and flows in a general westerly direction, entering Columbia River below the mouth of Wallawalla River. The country north of Umatilla is high and rolling. A number of canals divert water from the lower course of the stream to irrigate lands on either side.

Yakima River has its source in Keechelus Lake, on the eastern slope of the Cascade Mountains, in Kittitas County, Wash. Within a short distance it receives the waters of Kachess Lake, and 2½ miles above Clealum it receives the outlet of the last of the three large headwater lakes. It enters Columbia River 23 miles below Kiona, Wash.

Naches River has its source on the eastern slope of the Cascade Mountains, in Yakima County, Wash. It flows in a general southeasterly direction, entering Yakima River a short distance above North Yakima. Irrigation is practiced in the narrow valley along the lower course of the river, but its waters are of greater value for the irrigation of lands west of North Yakima. The river has considerable

fall and the water can easily be diverted by means of comparatively short canals. For this reason it is of more value for irrigation purposes than Yakima River, which has less fall.

Tieton River is the principal tributary of the Naches River and discharges into the latter about 17 miles above its junction with Yakima River, near North Yakima. Its source is in the Cascade Mountains in the vicinity of Cowlitz Pass. A peculiar feature of the stream is the turbid, milk-white appearance of the water, it being similar in this respect to White River, on the western slope of the Cascade Range. The water of the South Fork of the Tieton, 25 miles above the mouth, is however, perfectly clear. The forks head in the glaciers of a peak of the Cascades known locally as Goat Rock.

Spokane River rises in the northern part of Idaho, being the outlet of Lake Coeur d'Alene. It passes into Washington, flows in a northerly direction, and enters Columbia River near latitude 47° 52′ north. It is about 120 miles long.

Missoula River has its source in Silverbow County, Mont., and flows northerly until it receives the waters of Little Blackfoot River, when it takes a more northwesterly course. The name Missoula is usually applied to that portion of the river between the junction of Blackfoot and Hellgate rivers and the mouth of Pend Oreille River. From that point to its junction with Columbia River it is called Clark Fork of Columbia.

The source of Bitterroot River is in the high mountains which form the boundary line between Montana and Idaho. It flows in a northerly direction, entering Missoula River a short distance below the city of Missoula. The tributaries on the east side drain comparatively low hills and contribute little to the supply of the river. The west side branches, on the contrary, are numerous, draining a precipitous and heavily wooded area. Their discharges are regulated by many small lakes fed by banks of snow, which continue far into the summer before disappearing altogether. From Hamilton to Missoula, a distance of 48 miles, the fall of the river is 350 feet, or 7.3 feet to the mile.

Snake River, which is the largest affluent of the Columbia, rises on the southern slope of the Continental Divide in the Yellowstone National Park, draining the country west and southwest of Yellowstone Lake. From Shoshone, Lewes, and Hart Lakes, near its head, the river flows in a southerly direction through a timbered and mountainous country, resulting in a long period of high water. After continuing through this area for about 20 miles it broadens into Jackson Lake, a deep body of water about 3 miles wide and 8 miles long. Below the lake the river flows through Jackson Hole Valley—about 40 miles long and 8 miles wide—and then enters a long canyon near the Idaho-Wyoming line. All of the large tributaries come from the east, receiving their waters from the Wind River Range. The west side of the valley is bounded by the high Teton Mountains, from which

most of the drainage flows westward through Tieton River into North Fork of Snake River. It empties into Columbia River near Pasco Junction, in the State of Washington.

The headwater tributaries of Palouse River have their sources in western Idaho. After passing into Washington the streams unite to form Palouse River, which has a general southwesterly course, through a rolling country. Six miles below Hooper, Wash., the river bends suddenly to the south and enters its canyon, through which it flows until its junction with Snake River. A short distance above the mouth of the river are the Palouse Falls, approximately 130 feet high.

Weiser River drains Washington County, in the extreme western part of Idaho, and flows into Snake River at Weiser, Idaho.

The Boise drains a mountainous and well-wooded country in Elmore County, Idaho. The effects of the forests are shown in the high flow that is maintained throughout the summer season, in contrast to the discharge of Weiser River, farther to the west, which drains a more barren country. Below the gaging station, which is located in the canyon, a large number of canals divert water to irrigate lands in Boise Valley. The diversion of the water is now so great that frequent complaints of scarcity are heard.

Bruneau River rises in northern Nevada and flows in a general northerly course through southern Idaho, emptying into Snake River at a point about south of Boise. Fall River is one of the small tributaries of the Snake River at its headwaters in eastern Idaho. The following list includes the stations in the Columbia River drainage basin:

Umatilla River at Gibbon, Oreg.
Yakima River at Kiona, Wash.
Yakima River at Union Gap, Wash.
Naches River near North Yakima, Wash.
Tieton River near North Yakima, Wash.
Spokane River at Spokane, Wash.
Missoula River at Missoula, Mont.
Bitterroot River near Grantsdale, Mont.
Palouse River near Hooper, Wash.
Weiser River near Weiser, Idaho.
Boise River near Boise, Idaho.
Bruneau River near Grandview, Idaho.
Snake River at Montgomery Ferry, near Minidoka, Idaho.
Snake River (North Fork) near Ora, Idaho.
Fall River near Marysville, Idaho.

UMATILLA RIVER AT GIBBON, OREG.

The station at Gibbon, Oreg., was established July 22, 1896, and is located one-half mile west of the railroad station. The gage rod, which was located one-quarter of a mile below the railroad station, was carried away by a freshet in May, but the bench mark, a cross in black paint on the highest point of the rock to which the rod was fastened, still remains. It is 4.40 feet above datum. The same flood also carried away the entire equipment, consisting of a five-eighth-inch

cable with car, supports, tag, and stay wires. These were all renewed on September 10, 1902. The cable is situated one-half mile below the railroad station in its original position. Changes in the channel necessitated the selection of a better location for the gage rod a few hundred feet nearer to the cable and one-fourth of a mile below the railroad station. A new wire gage was established October 29, 1902. It consists of a horizontal rod attached to a beam projecting over the water and spiked to the top of the cribbing on the left shore about 10 feet north of the railroad track. The length from the end of the weight to the marker is 14.333 feet and the distance from the outside edge of the pulley to the zero of the gage scale is 6.02 feet. The bench mark is a spike on the top timber of the cribbing. Its elevation is 8.31 feet above the zero of the new gage. The initial point for soundings is the face of the tree to which the cable is attached on the right bank of the stream. The channel is straight and the bed is of gravel.

The following discharge measurements were made during 1902:

July 21: Gage height, 0.90 foot; discharge, 130 second-feet.
October 29: Gage height, 0.65 foot; discharge, 106 second-feet.
December 20: Gage height, 1.60 feet; discharge, 381 second-feet.

Daily gage height, in feet, of Umatilla River at Gibbon, Oreg.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.35	1.00	2.50	1.85	2.65	2.60	0.95	0.80	0.75	0.85	0.65	2.40
2	1.30	1.00	2.45	2.00	3.10	2.40	1.10	.80	.75	.85	.70	1.95
3	1.30	1.00	2.25	2.10	3.35	2.25	1.55	.80	.75	.85	.70	1.80
4	1.35	1.00	2.15	2.25	3.50	2.05	2.20	.80	.75	.85	.70	1.70
5	1.40	1.00	2.00	2.30	3.45	1.90	1.95	.80	.75	.85	.75	1.65
6	1.40	1.05	1.85	2.80	3.20	1.80	1.60	.80	.75	.85	.80	1.55
7	1.45	1.05	1.75	3.90	3.30	1.70	1.40	.80	.75	.85	1.10	1.50
8	1.45	1.10	1.70	3.95	3.40	1.65	1.25	.75	.75	.90	1.20	1.50
9	1.40	1.80	1.70	3.70	3.40	1.55	1.15	.75	.75	.90	1.20	3.10
10	1.40	2.50	1.75	3.40	3.45	1.50	1.10	.75	.75	.90	1.15	3.20
11	1.40	2.80	1.80	3.20	3.40	1.45	1.10	.75	.75	.90	1.10	2.95
12	1.40	2.80	1.90	2.95	3.30	1.40	1.05	.75	.75	.85	1.05	2.60
13	1.35	2.85	1.80	2.75	3.25	1.30	1.05	.75	.75	.85	1.00	2.35
14	1.35	2.90	1.70	2.60	3.20	1.25	1.05	.75	.75	.85	1.20	2.10
15	1.35	2.90	1.65	2.45	3.10	1.20	1.05	.75	.75	.85	1.20	2.00
16	1.30	2.90	1.60	2.50	3.05	1.20	1.00	.80	.75	.85	1.45	1.85
17	1.30	3.50	1.70	2.60	3.00	1.15	.95	.80	.75	.85	1.70	1.75
18	1.30	3.60	1.90	3.20	2.90	1.15	.95	.80	.75	.85	1.75	1.65
19	1.30	3.00	2.00	3.85	3.30	1.10	.90	.75	.85	.85	1.85	1.60
20	1.25	2.65	2.05	3.50	5.80	1.10	.90	.75	.85	.85	1.70	1.60
21	1.25	2.40	2.00	3.30	5.75	1.10	.90	.75	.85	.85	1.65	1.50
22	1.25	2.20	1.90	3.00	5.25	1.05	.90	.75	.85	.95	1.55	1.40
23	1.20	2.10	1.90	2.80	4.80	1.05	.90	.75	.85	1.00	1.45	1.40
24	1.20	2.25	1.90	2.65	4.40	1.05	.85	.75	.90	1.05	1.55	1.40
25	1.10	2.80	1.80	2.50	4.10	1.00	.85	.75	.90	1.05	1.60	1.80
26	1.10	2.75	1.75	2.40	3.90	1.00	.85	.75	.90	1.00	1.60	3.00
27	1.05	2.60	1.70	2.40	3.60	.95	.85	.75	.95	1.00	1.60	3.10
28	1.05	2.50	1.70	2.45	3.40	.95	.80	.75	.90	1.00	1.55	2.65
29	1.05	.....	1.65	2.50	3.25	.95	.80	.75	.85	.65	1.55	2.40
30	1.05	.....	1.70	2.60	3.00	.95	.80	.75	.85	.65	1.60	2.20
31	1.00	.....	1.75	.....	2.75	.....	.80	.75	.....	.65	.....	2.00

ting table for Umatilla River at Gibbon, Oreg., for 1902.

scharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
ond-feet.	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
50	1.4	330	2.8	1,100	4.5	2,555
63	1.6	412	3.0	1,255	5.0	3,055
78	1.8	502	3.2	1,415	5.5	3,555
98	2.0	600	3.4	1,575	6.0	4,055
135	2.2	707	3.6	1,735		
190	2.4	826	3.8	1,895		
256	2.6	957	4.0	2,055		

uated monthly discharge of Umatilla River at Gibbon, Oreg.

[Drainage area, 358 square miles.]

	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
.....	350	190	284	17,463	0.80	0.92
.....	1,735	190	801	44,481	2.27	2.36
.....	890	412	541	33,265	1.53	1.76
.....	2,015	526	1,140	67,835	3.23	3.60
.....	3,855	992	1,767	108,649	5.01	5.77
.....	957	175	348	20,707	.99	1.10
.....	707	135	228	14,019	.65	.75
.....	135	124	128	7,870	.36	.42
.....	175	124	136	8,093	.39	.44
.....	206	106	155	9,531	.44	.51
.....	526	106	302	17,970	.86	.96
.....	1,415	330	668	41,074	1.89	2.18
ar	3,855	106	542	390,957	1.54	20.77

YAKIMA RIVER AT KIONA, WASH.

This station is the lowest point at which measurements have been made on Yakima River, and is located at the wagon bridge one-fourth mile north of the railroad station at Kiona. The gage was established August 20, 1895, and consisted of two parts, one vertical and the other inclined at an angle of 30°. It was spiked to the east end of the south pier and anchored with rocks. The initial point for soundings is on the west side of the bridge, 100 feet south of the center of the south pier of the main span. The channel for about 200 feet both above and below the station is nearly straight and the water is quite swift. The right bank is low, but is well protected by a levee, and not subject to overflow. The left bank is high and rocky. The bed of the stream is of gravel and affords an excellent cross section for discharge measurements.

A wire gage was afterwards placed on the lower side of the bridge. The distance from the end of the weight to the index marker is 27.21 feet. From the end of the rod to the outside edge of the pulley wheel it is 2 feet. A new bench mark was established in 1901. It is the top of an iron spike in the east end of the cap of the first trestle bent of the bridge approach on the south side of the river. The elevation of the bench mark above the zero of the gage is 20.53 feet and above sea level 474.24 feet. The top of the 2-inch pulley wheel of the wire gage is 4.6[illegible] feet above this bench mark. When the marker on the wire gage is at zero, the bottom of the weight has an elevation of 453.71 feet.

Discharge measurements of Yakima River at Kiona, Wash.

Date.	Hydrographer.	Gage height.	Discharge
1902.		*Feet.*	*Second-feet*
March 25	Sydney Arnold	6.00	4,1[illegible]
April 11	do	7.76	7,0[illegible]
June 12	do	9.00	9,6[illegible]
June 23	do	8.00	8,3[illegible]
July 11	do	6.45	4,1[illegible]
September 2	do	2.95	2[illegible]
October 21	do	3.85	8[illegible]

Daily gage height, in feet, of Yakima River at Kiona, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	8.55	5.40	6.42	6.25	9.85	10.00	(a)	5.00	2.98	3.78	4.31	5.15
2	8.58	5.30	6.35	6.33	9.90	9.20	(a)	4.96	2.95	3.95	4.35	5.52
3	8.60	5.25	6.30	6.35	9.90	8.85	(a)	4.82	2.95	3.93	4.38	5.93
4	8.64	5.20	6.45	6.42	9.95	8.30	(a)	4.73	2.94	3.90	4.40	6.70
5	8.70	5.10	6.45	6.45	10.05	8.18	(a)	4.70	2.93	3.80	4.40	6.50
6	8.80	5.00	6.50	6.60	10.15	8.20	(b)	4.65	2.90	3.72	4.42	6.35
7	8.85	5.00	6.60	6.75	10.25	8.15	(b)	4.70	2.90	3.68	4.53	6.15
8	8.95	4.95	6.70	6.90	10.30	8.07	(b)	4.80	2.90	3.65	4.58	5.95
9	9.00	5.00	6.70	7.25	10.40	7.98	(b)	4.85	2.90	3.65	4.60	5.90
10	9.15	5.05	6.64	7.70	10.68	8.02	(b)	4.72	2.88	3.65	4.78	5.85
11	8.43	5.05	6.50	7.73	10.90	8.00	6.45	4.55	2.88	3.65	4.92	5.85
12	8.10	5.10	6.55	7.65	11.40	7.95	6.43	4.30	2.88	3.65	5.05	5.70
13	7.90	5.15	6.55	7.45	11.60	7.90	6.42	4.22	2.88	3.65	5.12	5.60
14	7.75	5.20	6.60	7.25	11.40	7.78	6.40	4.10	2.88	3.64	5.18	5.50
15	7.50	5.50	6.60	7.10	11.25	7.70	6.20	3.97	2.90	3.63	5.20	5.39
16	7.05	6.13	6.55	7.00	11.00	7.65	6.26	3.90	2.98	3.70	5.22	5.30
17	6.75	7.00	6.50	7.00	10.95	7.56	6.28	3.85	3.00	3.78	5.31	5.25
18	6.75	7.12	6.45	7.15	10.80	7.42	6.25	3.85	3.00	3.80	5.38	5.20
19	6.70	7.10	6.38	7.25	10.40	7.38	6.18	3.78	3.03	3.82	5.70	5.14
20	6.68	7.16	6.35	7.40	9.93	7.30	6.08	3.70	3.01	3.87	5.75	5.07
21	6.65	7.20	6.25	7.45	9.45	(a)	6.09	3.60	3.08	3.85	5.65	4.97
22	6.55	7.20	6.20	8.10	9.15	(a)	6.38	3.52	3.08	3.88	5.55	4.92
23	6.50	7.05	6.15	8.40	9.25	8.00	6.24	3.45	3.20	3.90	5.40	4.86
24	6.50	6.95	6.05	8.75	9.45	(a)	6.14	3.35	3.20	3.92	5.34	4.80
25	6.35	6.80	6.00	9.10	9.60	7.57	6.02	3.16	3.20	4.00	5.30	4.90
26	6.25	6.75	6.10	9.20	9.85	7.54	5.92	3.13	3.20	4.07	5.27	4.99
27	6.00	6.60	6.10	9.35	10.20	7.55	5.82	3.10	3.22	4.13	5.24	5.30
28	5.90	6.50	6.13	9.40	11.00	7.55	5.66	3.08	3.35	4.18	5.20	5.52
29	5.90	.....	6.15	9.65	11.50	7.42	5.42	3.05	3.58	4.22	5.15	5.70
30	5.75	.....	6.15	9.85	11.30	7.40	5.27	2.98	3.65	4.25	5.10	5.68
31	5.60	.....	6.20	.....	10.85	.....	5.15	2.98	.....	4.27	.....	6.10

[a] Observer absent. [b] Gage broken.

Rating table for Yakima River at Kiona, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.8	200	5.8	3,310	8.8	9,340	11.8	17,480
3.0	270	6.0	3,630	9.0	9,780	12.0	18,080
3.2	370	6.2	3,970	9.2	10,240	12.2	18,680
3.4	490	6.4	4,320	9.4	10,700	12.4	19,280
3.6	620	6.6	4,680	9.6	11,160	12.6	19,880
3.8	760	6.8	5,060	9.8	11,620	12.8	20,480
4.0	910	7.0	5,450	10.0	12,080	13.0	21,080
4.2	1,070	7.2	5,850	10.2	12,680	13.2	21,680
4.4	1,260	7.4	6,270	10.4	13,280	13.4	22,280
4.6	1,490	7.6	6,700	10.6	13,880	13.6	22,880
4.8	1,760	7.8	7,140	10.8	14,480	13.8	23,480
5.0	2,060	8.0	7,580	11.0	15,080	14.0	24,080
5.2	2,365	8.2	8,020	11.2	15,680	14.2	24,680
5.4	*2,675*	*8.4*	8,460	11.4	16,280	14.4	25,280
5.6	*2,990*	*8.6*	8,900	11.6	16,880	.....	.....

Estimated monthly discharge of Yakima River at Kiona, Wash.

[Drainage area, 5,230 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Dep inc
1902.						
January	10,125	560	6,414	394,381	1.23	
February	5,850	1,986	3,663	203,433	.70	
March	4,870	3,630	4,281	263,228	.82	
April	11,735	4,055	6,869	408,734	1.31	
May	16,880	10,125	13,388	823,196	2.56	
June	12,080	6,060	7,416	441,283	1.42	
July	6,123	2,288	4,245	261,015	.81	
August	2,060	262	1,009	62,041	.19	
September	655	224	303	18,030	.06	
October	1,133	641	808	49,682	.15	
November	3,230	1,170	2,134	126,982	.41	
December	4,870	1,760	2,917	179,359	.56	
The year	16,880	224	4,454	3,231,364	.85	1

YAKIMA RIVER AT UNION GAP, WASH.

Yakima River enters Columbia River just above the town of Pa The first measurement of the river was made at this point on Au 14, 1893. At that time there was an old vertical river rod attache the central pier of the bridge. As the foot of this at low water covered by rock and could not be read, an inclined gage was pu position at the west end of the county bridge. This consisted of pieces of timber having a total length of 24 feet. These were fir secured to timbers, bedded, and loaded with rock. The gage rod painted white and lettered in vertical feet and tenths of a foot. A this new gage was located, it was ascertained that the readings on old gage would be 1.13 feet higher than on the new. The zero of new gage was 19.02 feet below the top of the rail of the Nortl Pacific Railroad immediately west of the west end of the bridge, w was about 40 feet from the gage. The high-water mark at that t showed that a flood had risen to 8.80 feet on the old gage. Read at this point were begun on October 2, 1893, and continued during following winter and spring until May 19, 1894. Owing to the struction of the gage by floods the station was for a time abandoı

During August, 1895, Arthur P. Davis visited the locality and foı *that the section* was not favorable for making discharge meası *ments. He* accordingly selected the present station, which is lo *at Union Gap,* 6 miles below North Yakima, Wash., and 1,9

below the highway bridge. It is about 3 miles above the intake of the Sunnyside canal. The gage rod is inclined and is attached to a willow stump and posts set in the ground. The bench mark is the highest point of a large rock mound 43 feet north of the gage and 6.5 feet east of the fence, and is at an elevation of 17.52 feet above gage datum. The equipment consists of cable, car, and tagged wire. The station is of value as it is the only point near the large irrigated area above and below which is unaffected by the taking out of water in irrigating canals.

Discharge measurements of Yakima River at Union Gap, Wash.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
July 5	Sydney Arnold	6.75	5,352
September 3	do	4.10	917
November 3	do	4.55	1,391

Daily gage height, in feet, of Yakima River at Union Gap, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	6.60	5.30	6.00	5.60	7.40	9.00	7.00	5.60	4.10	4.60	4.40	6.00
2	6.60	5.20	6.20	5.60	7.30	8.30	7.00	5.60	4.10	4.60	4.40	6.30
3	6.40	5.20	6.20	5.50	7.30	7.90	6.90	5.30	4.10	4.60	4.40	6.60
4	6.30	5.00	6.30	5.50	7.50	7.50	6.90	5.10	4.10	4.60	4.60	6.60
5	6.90	5.00	6.30	5.50	7.80	7.50	6.70	5.10	4.10	4.50	4.60	6.30
6	7.00	5.00	6.20	5.90	8.00	7.30	6.70	5.10	4.10	4.50	4.60	6.00
7	7.40	5.00	6.30	7.00	8.20	7.30	6.60	5.10	4.10	4.40	4.60	6.00
8	7.60	4.90	6.30	7.60	8.20	7.20	6.60	5.00	4.10	4.40	4.60	5.90
9	8.00	5.10	6.30	7.60	8.80	7.40	6.60	5.00	4.10	4.40	4.60	5.90
10	8.20	5.10	6.30	7.60	8.90	7.50	6.30	4.90	4.00	4.20	4.60	5.60
11	8.00	5.30	6.20	7.00	9.50	7.90	6.30	4.90	4.00	4.20	4.80	5.60
12	7.60	5.30	6.20	6.90	10.10	8.20	6.30	4.90	4.00	4.20	5.00	5.80
13	7.20	5.30	6.20	6.90	10.10	8.00	6.10	4.90	4.00	4.20	5.10	5.30
14	6.90	5.30	6.20	6.90	9.80	7.90	6.10	4.80	4.00	4.30	5.20	5.30
15	6.70	5.30	6.20	6.90	9.50	7.50	6.10	4.80	4.00	4.30	5.20	5.30
16	6.60	5.70	6.00	7.00	9.50	7.50	6.00	4.70	4.00	4.30	5.40	5.20
17	6.40	6.60	6.00	7.00	9.50	7.30	6.00	4.70	4.00	4.30	5.40	5.10
18	6.40	6.60	6.00	7.10	9.50	7.30	6.00	4.60	4.00	4.40	5.40	5.00
19	6.20	7.00	5.90	7.30	9.30	7.30	6.00	4.60	4.10	4.40	5.60	4.90
20	6.00	7.00	5.90	7.90	9.30	7.30	6.00	4.50	4.10	4.40	5.60	4.90
21	5.90	6.90	5.90	8.10	8.90	7.00	6.00	4.50	4.10	4.40	5.50	4.90
22	5.90	6.90	5.90	8.00	8.30	7.00	5.90	4.40	4.10	4.40	5.40	5.00
23	5.70	6.90	5.80	7.90	8.00	7.30	5.90	4.40	4.10	4.30	5.30	5.00
24	5.70	6.90	5.80	7.90	8.00	7.30	5.90	4.30	4.10	4.30	5.30	5.30
25	5.40	6.60	5.80	7.80	9.00	7.80	5.90	4.30	4.10	4.30	5.40	5.60
26	5.40	6.60	5.80	7.80	9.40	7.80	5.90	4.30	4.10	4.30	5.50	5.60
27	5.20	6.30	5.70	7.60	9.80	7.80	5.80	4.20	4.10	4.30	5.50	5.80
28	5.20	6.00	5.70	7.50	10.20	7.60	5.80	4.20	4.40	4.30	5.60	5.80
29	5.00	.....	5.70	7.50	10.10	7.30	5.70	4.20	4.40	4.30	5.60	5.60
30	5.20	.....	5.70	7.40	9.80	7.30	5.70	4.20	4.50	4.30	5.80	5.60
31	5.40	.....	5.70	.....	9.50	.....	5.60	4.20	.....	4.40	.....	5.60

[a] Rating table for Yakima River at Union Gap, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.0	820	5.8	3,160	7.6	7,800	9.4	15,000
4.2	1,020	6.0	3,550	7.8	8,500	9.6	15,900
4.4	1,230	6.2	3,980	8.0	9,200	9.8	16,800
4.6	1,450	6.4	4,450	8.2	10,000	10.0	17,700
4.8	1,690	6.6	4,950	8.4	10,800	10.5	19,950
5.0	1,940	6.8	5,450	8.6	11,600	11.0	22,200
5.2	2,210	7.0	5,950	8.8	12,400	11.5	24,450
5.4	2,500	7.2	6,550	9.0	13,200	12.0	26,700
5.6	2,810	7.4	7,150	9.2	14,100		

[a] Measurements made since this table was constructed show that it is correct below a gage height of 5.00 feet; above that height the discharge given in the table is too low.

Estimated monthly discharge of Yakima River at Union Gap, Wash.

[Drainage area, 3,300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	10,000	1,940	4,804	295,386	1.46	1.6
February	5,950	1,810	3,481	193,325	1.05	1.0
March	4,210	2,980	3,621	222,647	1.10	1.2
April	9,600	2,650	6,442	383,326	1.95	2.1
May	18,600	6,850	13,105	805,795	3.97	4.5
June	13,200	5,950	7,800	464,132	2.36	2.6
July	5,950	2,810	4,057	249,455	1.23	1.4
August	2,810	1,020	1,625	99,979	.49	.5
September	1,340	820	925	55,041	.28	.3
October	1,450	1,020	1,196	73,539	.36	.4
November	3,160	1,230	2,117	125,970	.64	.7
December	4,950	1,810	2,869	176,408	.87	1.0
The year	18,600	820	4,337	3,145,003	1.31	17.8

NACHES RIVER NEAR NORTH YAKIMA, WASH.

This station was established August 14, 1893, by F. H. Newell, at a point a few hundred yards above the mouth of Naches River, near the bridge of the Northern Pacific Railroad. The vertical gage was nailed to the cribwork on the right-hand side of the river, above the railroad bridge, and could be read easily from the track. The 12-foot mark was 9.97 feet below the top of the rail on the bridge, the gage being about 60 feet easterly from the rail. The top of the iron pier, on the southeast end of the county bridge, was 5.87 feet above this 12-foot mark. Measurements were made from the county bridge. The locality was, however, not favorable for the purpose, as the water s very swift, and was broken by the piers of the bridge. Owing to he difficulty of securing accurate measurements the readings were liscontinued on September 20, 1894, and not resumed until August 9, 1895. The flood of November, 1896, modified the channel very reatly, depositing a large mass of coarse gravel and small bowlders long the right side of the channel at the section, so that the rod was bout 50 feet from the edge of the water at low stages. The curent is swift, even at low water. On account of the instability of he channel the station was abandoned in February, 1897, although a umber of discharge measurements were made during the season. The station was located below the heads of a number of ditches. May 19, 1897, a station was established on Yakima River, 5 miles bove the mouth of the Naches, at the Northern Pacific Railway bridge near Selah, Wash., with the idea that the difference in discharge between this station and the one at Union Gap would give approximately the discharge of Naches River. Two ditches, those of Moxee Valley, are taken out between the two points, but their amount is about counterbalanced by that received from Atanum Creek and the wastage at Old Town.

The North Yakima station was reestablished on February 1, 1898, and the station at Selah, on Yakima River, was discontinued. Since he reestablishment of the Naches station the river channel has been n a condition more favorable for meter observations than formerly. Discharge measurements are made from the lower side of the highway bridge. A new horizontal gage rod, with wire and weight, was ttached to the main span of the Northern Pacific Railway bridge t the mouth of the Naches, a few hundred feet downstream from he highway bridge. The length of the gage wire from index to ot of weight was 30.41 feet. The pulley distance was 5.844 feet. The elevation of top of pulley was 24.57 feet. The bench mark as the top of the north end of east sill of clearance posts, about 150 eet north of Northern Pacific Railway bridge. Elevation, 23.766 feet bove zero of gage. On December 27, 1898, Mr. Arnold connected the *ighway bridge with this* bench mark. The top of the northeast

concrete pier was found to be at an elevation of 22.09 feet, and the top of the bridge post at the 150-foot mark at an elevation of 26.76 feet above zero. The distance from the top of the post to the surface of the water has been carefully measured at each discharge measurement, so that the exact river height at the highway bridge is known.

On June 20, 1901, the gage rod and bench mark having been disturbed during alterations to the railroad bridge and approaches, a new 4-inch by 4-inch inclined gage rod was established on the left bank of the river, 30 feet downstream from the railroad bridge. The bench mark is U.S.G.S. B.M. established by H. S. Crowe. It is a copper plug marked "1090 T." Its elevation is 1,089.959 feet above sea level. It is located on Naches River opposite the point where it empties into Yakima River, in the center of the west end of the stone pier of the railroad bridge. The elevation of the zero of the gage is 1,070.22 feet above sea level. The initial point for measurements is the center of the east pier of the highway bridge. The lower section of the gage rod is inclined at an angle of 36° 30′ with the horizontal. The upper section is inclined at an angle of 80°.

Owing to unfavorable conditions at the highway bridge due to the accumulation of drift and a changing channel, a cable station has been established between the highway bridge and the railway bridge. A careful measurement under favorable conditions made in 1903 at the new station made by Geo. H. Bliss gave a discharge of 461 second-feet at 5.25 feet of gage height.

Discharge measurements of Naches River near North Yakima, Wash.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 14	Sydney Arnold	6.65	1,657
April 30	do	7.20	2,581
May 8	do	8.45	5,788
June 13	do	7.80	3,811
August 28	do	5.20	302
August 28	do	5.20	[a] 528
November 4	do	5.45	459

[a] Measured at Nelson bridge, 4 miles above gaging station.

Daily gage height, in feet, of Naches River near North Yakima, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	6.50	5.80	6.50	6.20	7.20	8.10	7.30	6.20	5.20	5.40	5.50	6.20
2	6.40	5.80	6.40	6.20	7.10	7.90	7.30	6.10	5.20	5.40	5.60	6.40
3	6.40	5.80	6.30	6.30	7.10	7.60	7.20	6.05	5.20	5.40	5.70	6.20
4	6.60	5.80	6.30	6.30	7.20	7.40	7.20	6.00	5.10	5.40	5.60	6.10
5	7.05	5.80	6.30	6.30	7.30	7.40	7.10	6.00	5.10	5.30	5.60	6.10
6	7.50	5.80	6.30	6.90	7.50	7.30	7.05	5.90	5.10	5.20	5.50	6.00
7	7.50	5.80	6.30	7.50	7.90	7.30	7.00	5.90	5.10	5.20	5.50	5.95
8	8.40	5.80	6.40	7.60	8.90	7.70	6.90	5.90	5.10	5.20	5.60	5.90
9	8.20	5.75	6.45	7.30	8.70	8.10	6.80	5.80	5.10	5.20	5.80	6.00
10	7.80	5.70	6.50	7.20	8.80	8.20	6.80	5.80	5.10	5.20	6.00	6.10
11	7.60	5.70	6.50	6.90	8.85	8.20	6.80	5.80	5.10	5.20	6.00	6.10
12	7.50	5.70	6.50	6.80	8.90	8.10	6.80	5.70	5.10	5.20	6.00	6.10
13	7.40	5.70	6.50	6.75	8.80	7.90	6.80	5.70	5.10	5.20	6.00	6.10
14	7.20	5.70	6.40	6.70	8.80	7.80	6.80	5.60	5.05	5.20	6.10	6.00
15	6.90	5.80	6.40	6.80	8.70	7.75	6.80	5.60	5.00	5.20	6.10	5.90
16	6.70	6.40	6.30	6.90	8.60	7.70	6.80	5.50	5.00	5.30	6.20	5.80
17	6.60	7.00	6.20	7.40	8.50	7.70	6.80	5.50	5.00	5.40	6.30	5.80
18	6.50	7.00	6.20	7.50	8.30	7.70	6.70	5.50	5.00	5.50	6.40	5.70
19	6.45	6.90	6.20	8.20	8.10	7.60	6.70	5.50	5.00	5.50	6.30	5.70
20	6.40	6.90	6.20	8.05	7.80	7.60	6.70	5.40	5.00	5.50	6.10	5.70
21	6.40	6.80	6.20	7.90	7.80	7.60	6.70	5.40	5.00	5.50	6.00	5.70
22	6.30	6.70	6.20	7.80	7.70	7.80	6.70	5.40	5.00	5.40	5.90	5.70
23	6.20	6.70	6.15	7.70	7.90	8.00	6.70	5.30	5.00	5.40	5.90	5.80
24	6.10	6.70	6.10	7.60	8.10	8.10	6.60	5.30	5.00	5.40	5.90	5.80
25	5.80	6.70	6.10	7.50	8.25	8.10	6.60	5.30	5.00	5.40	5.80	6.00
26	5.80	6.70	6.10	7.50	8.40	7.90	6.50	5.30	5.20	5.40	5.80	6.20
27	5.80	6.60	6.10	7.45	9.00	7.80	6.40	5.20	5.30	5.40	5.80	6.60
28	5.80	6.60	6.10	7.40	9.40	7.60	6.30	5.20	5.40	5.40	5.70	6.50
29	5.80	.....	6.10	7.30	9.20	7.45	6.30	5.20	5.50	5.40	5.70	6.40
30	5.80	.....	6.10	7.20	8.70	7.30	6.20	5.20	5.50	5.40	5.95	6.40
31	5.80	.....	6.10	.....	8.30	.....	6.20	5.20	.....	5.40	.....	6.30

Rating table for Naches River at North Yakima, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
5.0	200	6.2	1,125	7.4	2,950	8.6	6,290
5.2	300	6.4	1,350	7.6	3,360	8.8	6,830
5.4	425	6.6	1,595	7.8	3,810	9.0	7,470
5.6	570	6.8	1,860	8.0	4,370		
5.8	735	7.0	2,152	8.2	5,010		
6.0	920	7.2	2,580	8.4	5,650		

Estimated monthly discharge of Naches River near North Yakima, Wash.

[Drainage area, 1,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	5,650	735	1,943	119,470	1.94	2.24
February	2,152	650	1,210	67,200	1.21	1.26
March	1,470	1,020	1,211	74,461	1.21	1.39
April	5,010	1,125	2,638	156,972	2.64	2.95
May	8,750	2,311	5,282	324,777	5.28	6.08
June	5,010	2,760	3,782	225,045	3.78	4.22
July	2,760	1,125	1,845	113,445	1.85	2.13
August	1,125	300	589	36,216	.59	.68
September	495	200	263	15,650	.26	.29
October	495	300	390	23,919	.39	.45
November	1,350	495	820	48,793	.82	.91
December	1,595	650	975	59,950	.98	1.13
The year	8,750	200	1,746	1,265,898	1.74	23.73

TIETON RIVER NEAR NORTH YAKIMA, WASH.

The gaging station on this stream was established April 14, 1902, at a point immediately below the mouth of Oak Creek, in sec. 3, T. 14 N., R. 16 E. of the Willamette meridian, and about 22 miles from North Yakima by road. The gage rod is inclined at an angle of 55° with the horizontal and is on the left bank of the stream. It consists of a 1 by 5 inch cedar plank supported and braced by stout logs. The equipment with which measurements are made consists of a five-eighth-inch galvanized-iron cable supporting a wooden car, tag wire, and stay wire. The initial point for soundings is a cross chiseled in a ledge with a black ring painted around it. It is under the cable, 4 feet east of the west shear legs. The observer is Omer Tetherow, a farmer. There are no side channels and the banks are not subject to overflow. The bed of the stream is rocky, with shifting gravel bars, which make it difficult to find suitable cross-sections for meter measurements. The point selected for the station is, however, a fairly good one, and the channel is straight both above and below the station for several hundred yards.

Discharge measurements of Tieton River near North Yakima, Wash.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
21	Sydney Arnold	8.90	1,471
28	do	8.55	1,106
6	do	8.45	906
st 25	do	7.30	392
nber 16	do	6.90	306
er 27	do	6.55	228
nber 29	do	6.80	289

Daily gage height, in feet, of Tieton River near North Yakima, Wash.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
		8.10	8.85	8.60	7.98	7.10	6.80	6.60	7.93
		8.00	8.70	8.43	7.83	7.12	6.75	6.73	7.45
		8.00	8.55	8.30	7.70	7.15	6.75	6.80	7.30
		8.00	8.45	8.35	7.68	7.20	6.73	6.70	7.25
		8.10	8.40	8.50	7.68	7.13	6.72	6.60	7.08
		8.40	8.40	8.28	7.68	7.20	6.72	6.65	7.00
		8.80	8.40	8.13	7.83	7.26	6.75	6.75	7.00
		9.40	8.70	8.13	7.88	7.25	6.75	7.23	7.00
		9.60	9.25	8.20	7.75	7.18	6.72	7.33	7.00
		9.75	9.30	8.20	7.70	7.15	6.75	7.18	7.50
		9.90	9.20	8.25	7.55	7.05	6.75	7.13	7.33
		9.50	8.95	8.25	7.65	7.03	6.73	7.08	7.23
		9.40	8.90	8.10	7.53	6.92	6.68	6.95	7.10
		9.40	8.85	8.13	7.53	7.00	6.70	6.93	6.95
		9.40	8.85	8.28	7.48	7.05	6.70	6.90	7.00
		9.60	8.90	8.40	7.43	6.95	6.90	7.13	7.48
		9.25	8.60	8.20	7.33	6.87	6.93	7.45	6.65
		9.05	8.65	8.13	7.23	6.82	6.80	7.35	6.63
		8.85	8.65	8.25	7.18	6.85	6.70	7.18	6.58
		8.70	8.80	8.35	7.20	6.82	6.70	7.13	6.98
		8.60	8.90	8.40	7.23	6.75	6.65	7.05	8.80
		8.70	9.03	8.30	7.28	6.75	6.70	7.00	6.90
		8.70	9.30	8.30	7.28	6.72	6.60	6.93	6.85
	8.50	8.80	9.33	8.23	7.25	6.75	6.60	6.95	6.68
	8.40	9.00	9.23	8.13	7.22	6.72	6.60	6.90	7.40
	8.40	9.45	8.88	8.10	7.25	6.72	6.60	6.85	8.10
	8.30	10.05	8.75	8.18	7.15	7.27	6.60	6.85	7.60
	8.30	10.20	8.63	7.93	7.20	7.03	6.70	6.85	7.50
	8.30	9.65	8.50	7.80	7.10	6.88	6.75	6.80	7.33
	8.20	9.30	8.62	7.73	7.10	6.83	6.65	6.85	7.25
		9.05		7.95	7.05		6.65		7.28

Rating table for Tieton River near North Yakima, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-fe*
6.0	120	7.2	372	8.4	900	9.6	2,310
6.2	160	7.4	420	8.6	1,110	9.8	2,550
6.4	200	7.6	484	8.8	1,350	10.0	2,790
6.6	240	7.8	560	9.0	1,590		
6.8	284	8.0	640	9.2	1,830		
7.0	328	8.2	750	9.4	2,070		

Estimated monthly discharge of Tieton River near North Yakima, Wash.

[Drainage area, 289 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth inche
1902.						
May	3,030	640	1,693	104,100	5.86	
June	1,986	900	1,378	82,000	4.77	
July	1,110	533	779	47,900	2.70	
August	632	339	450	27,670	1.56	
September	390	269	327	19,460	1.13	
October	313	236	265	16,290	.92	
November	435	240	321	19,100	1.11	
December	1,350	236	409	25,150	1.42	

SPOKANE RIVER AT SPOKANE, WASH.

The falls at Spokane, aggregating 142 feet in height, have utilized to a considerable extent by a number of flour mills, as we by the power plant of the Washington Water Power Company, w furnishes electric power for the street-car service and for the ligl of the city. The river station established by C. C. Babb, Octobe 1896, is a short distance above Spokane Falls, at the bridge of Oregon Railway and Navigation Company. The rod of the first gage was fastened to the upper guard rail in the west span of the br The distance from the end of the weight to the index was 22.00 and from the zero of the rod to the outside edge of the pulley feet. The gage was connected with a bench mark of the city neering department and referred to sea level, the rod datum 1,880 feet above sea level. The channel is straight for some dist above and below the section. The bed is gravelly and is practi unchangeable. The banks are high and are only overflowed du extraordinary floods.

ing 1901 new gages and bench marks were established at this The bench mark is a railroad spike driven into the electric-pole close to and on the south side of the railroad track, at the end of the bridge, at an elevation of 1,896.86 feet. The new gage on the north side of the west span of the bridge is the one for recording the gage height. The zero of this gage is at an ion of 1,879.35 feet, coinciding exactly with the position of the of the old gage. The distance from the end of the weight to arker is 22 feet, the same as for the old gage, but the distance the zero of the rod to the outside edge of the pulley is now 1.90 As a safeguard, a new vertical gage rod has also been placed on est face of the west pier of the bridge, the datum of which cor-nds with that of the wire gage.

Oregon Railway and Navigation Company's bridge to which the is fastened and from which measurements of flow are taken, has under reconstruction during 1902, so that no gagings could be during that year. The bed of the river, however, has not changed, he 1901 rating table is applicable for the 1902 discharges.

Daily gage height, in feet, of Spokane River at Spokane, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
	3.20	3.15	4.70	3.70	6.00	9.60	4.55	3.80	2.15	1.75	1.70	3.00
	3.20	3.10	4.75	3.70	6.00	9.40	4.45	3.75	2.10	1.75	1.70	3.00
	3.20	3.00	4.80	3.70	6.00	9.20	4.45	3.65	2.05	1.75	1.70	3.05
	3.20	3.00	4.80	3.70	6.00	9.00	4.55	3.55	2.00	1.75	1.75	3.05
	3.20	2.95	4.80	3.75	6.05	8.75	4.85	3.45	2.00	1.75	1.75	3.05
	3.25	2.90	4.75	3.85	6.05	8.50	6.05	3.40	2.00	1.75	1.75	3.05
	3.30	2.80	4.75	3.95	6.05	7.90	6.45	3.30	2.00	1.75	1.75	3.05
	3.50	2.80	4.70	4.10	6.15	7.80	6.90	3.20	2.00	1.75	1.75	3.00
	3.90	2.80	4.70	4.45	6.40	7.60	7.05	3.10	2.00	1.75	1.90	3.00
	4.25	2.85	4.70	4.70	6.60	7.40	7.10	3.05	1.95	1.70	2.25	3.05
	4.45	2.80	4.70	4.90	6.95	7.20	7.05	3.00	1.90	1.70	2.50	3.15
	4.70	2.80	4.70	5.00	7.20	7.20	6.95	2.95	1.90	1.70	2.60	3.25
	4.70	2.80	4.70	5.00	7.40	7.00	6.80	2.90	1.90	1.70	2.70	3.35
	4.70	2.80	4.70	5.00	7.60	7.00	6.65	2.85	1.90	1.70	2.80	3.50
	4.70	2.75	4.75	5.00	7.75	6.80	6.50	2.75	1.90	1.70	2.85	3.55
	4.60	2.75	4.70	5.00	8.00	6.70	6.30	2.75	1.85	1.70	2.90	3.50
	4.55	2.80	4.65	5.00	8.25	6.50	6.15	2.70	1.85	1.70	2.90	3.45
	4.40	2.95	4.60	5.00	8.40	6.15	5.95	2.65	1.80	1.65	3.00	3.45
	4.30	3.30	4.50	5.10	8.50	6.05	5.75	2.60	1.80	1.60	3.10	3.35
	4.30	3.65	4.45	5.30	8.50	6.00	5.60	2.60	1.75	1.60	3.30	3.25
	4.20	3.85	4.40	5.55	8.55	5.80	5.45	2.50	1.75	1.60	3.30	3.20
	4.10	3.95	4.35	5.80	8.70	5.70	5.25	2.50	1.75	1.55	3.25	3.15
	4.05	4.10	4.25	5.90	9.05	5.55	5.10	2.50	1.75	1.55	3.25	3.15
	3.95	4.10	4.20	6.00	9.40	5.40	5.00	2.50	1.75	1.55	3.25	3.10
	3.80	4.20	4.15	6.05	9.70	5.30	4.90	2.45	1.75	1.50	3.15	3.05
	3.70	4.35	4.10	6.10	9.80	5.15	4.70	2.35	1.75	1.50	3.15	3.05
	3.60	4.50	4.05	6.05	9.80	5.00	4.50	2.35	1.75	1.50	3.05	3.05
	3.45	4.60	4.00	6.05	9.70	4.90	4.40	2.30	1.75	1.60	3.00	3.05
	3.35	.....	3.90	6.05	9.70	4.75	4.30	2.25	1.75	1.60	2.95	3.10
	3.25	.....	3.85	6.00	9.70	4.65	4.20	2.20	1.75	1.60	2.95	3.15
	3.20	.....	3.80	.....	9.70	.....	4.00	2.20	.....	1.60	.....	3.15

Rating table for Spokane River at Spokane, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	1,341	3.8	6,523	6.6	14,253	9.4	23,800
1.2	1,611	4.0	7,000	6.8	14,885	9.6	24,531
1.4	1,897	4.2	7,489	7.0	15,525	9.8	25,269
1.6	2,199	4.4	7,990	7.2	16,173	10.0	26,012
1.8	2,517	4.6	8,503	7.4	16,829	10.2	26,759
2.0	2,851	4.8	9,028	7.6	17,493	10.4	27,510
2.2	3,200	5.0	9,565	7.8	18,165	10.6	28,265
2.4	3,566	5.2	10,114	8.0	18,845	10.8	29,024
2.6	3,946	5.4	10,673	8.2	19,533	11.0	29,787
2.8	4,340	5.6	11,243	8.4	20,228	11.2	30,554
3.0	4,749	5.8	11,824	8.6	20,928	11.4	31,325
3.2	5,172	6.0	12,416	8.8	21,636	11.6	32,099
3.4	5,609	6.2	13,019	9.0	22,351	11.8	32,875
3.6	6,059	6.4	13,631	9.2	23,073	12.0	33,653

Estimated monthly discharge of Spokane River at Spokane, Wash.

[Drainage area, 4,005 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	8,764	5,172	6,759	415,595	1.69	1.95
February	8,503	4,241	5,453	302,844	1.36	1.42
March	9,028	6,523	8,215	505,121	2.05	2.36
April	12,716	6,289	9,618	572,311	2.40	2.68
May	25,269	12,416	18,558	1,141,087	4.63	5.34
June	24,531	8,634	15,110	899,107	3.77	4.21
July	15,848	7,000	11,223	690,075	2.80	3.23
August	6,523	3,200	4,464	274,481	1.11	1.28
September	3,112	2,437	2,647	157,507	.66	.74
October	2,437	2,046	2,289	140,745	.57	.66
November	5,389	2,356	4,010	238,612	1.00	1.12
December	5,946	4,749	5,115	314,509	1.28	1.48
The year	25,269	2,046	7,788	5,651,994	1.94	26.47

MISSOULA RIVER AT MISSOULA, MONT.

This station, established July 10, 1898, is located at Higgins Avenue bridge in Missoula. The river at this point flows in two channels, and in order to study their fluctuations a second rod was placed on the south channel January 28, 1899. This second rod is vertical and attached to the pier of the bridge. The readings of the two rods were made to correspond on the date of the establishment of the second rod. The original rod is known as rod No. 1, and the gage in the south channel is known as rod No. 2. Discharge measurements are always made at the bridge of the Bitterroot Valley division of the Northern Pacific Railway, some distance below the Higgins Avenue bridge. The river at this point is practically in one channel, except in times of flood, when some water finds its way through a slough 600 feet south of the bridge. On account of the difficulty of accurately measuring the fluctuations of the river at rods Nos. 1 and 2 a third rod was placed May 27, 1899, below the junction of the two branches and 150 yards east of the railroad bridge. The rod at this point consists of a horizontal 20-foot timber bolted to a cottonwood tree immediately below the buildings of the Garden City Bottling Works. The rod is securely braced with timbers both above and below and guyed by wires on both sides. To the horizontal timber is attached a wire gage, the length of which is 22 feet. The bench mark consists of a United States Geological Survey iron post, at the junction of McCormick and West Cedar streets, 100 yards east of the gage, on the north side of the highway. Its elevation above sea is 3,194.642 feet. The top of the horizontal bar of the gage, at a point exactly over the iron bolt which holds the rod to the cottonwood tree, is 3,178.338 feet. The height of the river was read at the three rods during 1899, but all subsequent readings have been made from No. 3.

During 1902 the following discharge measurements were made by I. B. Waters:

April 24: Gage height, 4.61 feet; discharge, 2,570 second-feet.
April 24: Gage height, 4.59 feet; discharge, 2,542 second-feet.
July 12: Gage height, 5.97 feet; discharge, 5,302 second-feet.
August 27: Gage height, 4.02 feet; discharge, 1,941 second-feet.

Daily gage height, in feet, of Missoula River at Missoula, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	(a)	(a)	3.88	3.70	4.73	9.72	5.87	4.67	3.90	3.90	3.87	3.70
2	.....	.....	3.83	3.68	4.80	9.47	5.92	4.57	3.90	3.80	3.88	3.70
3	.....	.....	3.75	3.73	4.83	9.15	6.15	4.42	3.85	3.80	3.80	3.60
4	.....	.....	3.73	3.90	4.85	8.90	6.47	4.45	3.82	3.82	3.80	3.65
5	.....	.....	3.78	4.40	4.80	8.50	6.50	4.40	3.77	4.05	3.82	.....
6	.....	.....	3.80	4.35	4.73	8.00	6.70	4.35	3.87	3.87	3.80	(a)
7	.....	.....	3.80	4.53	4.88	7.75	6.57	4.32	3.72	3.77	3.82	.....
8	.....	.....	3.88	4.78	5.23	7.57	6.37	4.27	3.80	3.77	3.98	.....
9	.....	(a)	3.85	4.80	5.65	7.42	6.27	4.25	3.77	3.80	4.10	.....
10	.....	.....	3.93	4.53	6.35	8.23	6.15	4.35	3.77	3.82	4.18	4.17
11	.....	.....	3.93	4.30	6.78	8.32	6.10	4.15	3.70	3.85	4.32	4.05
12	.....	.....	3.90	4.13	7.28	8.20	6.05	4.15	3.72	3.90	4.20	4.00
13	.....	.....	3.90	4.13	8.18	7.90	5.97	4.12	3.75	3.85	4.20	3.92
14	.....	.....	3.88	4.05	7.72	7.67	5.82	4.15	3.70	3.83	4.15	3.90
15	.....	(a)	3.78	4.05	8.65	7.00	5.75	4.30	3.72	3.85	4.15	3.80
16	.....	.....	3.63	4.10	9.52	7.45	5.65	4.25	3.75	3.80	4.10	.....
17	3.25	.....	3.75	4.23	9.42	7.32	5.60	4.17	3.80	3.85	4.00	.....
18	.....	.....	3.75	4.55	9.20	6.82	5.75	4.32	3.77	3.87	4.00	(a)
19	.....	.....	3.75	4.73	8.77	6.62	5.80	4.30	3.80	3.80	4.02	.....
20	.....	.....	3.73	4.83	8.60	6.47	5.65	4.27	3.82	3.80	3.95	.....
21	.....	.....	3.73	4.88	8.75	6.37	5.55	4.17	3.97	3.80	3.90	.....
22	.....	(a)	3.75	4.80	9.10	6.25	5.42	4.15	3.80	3.80	3.80	.....
23	.....	.....	3.58	4.63	9.22	6.27	5.35	4.10	3.80	3.80	3.70	.....
24	(a)	.....	3.53	4.60	9.22	6.35	5.22	4.10	3.82	3.83	3.72	(a)
25	.....	.....	3.60	4.60	9.22	6.32	5.15	4.12	3.75	3.87	3.70	.....
26	.....	4.05	3.75	4.58	9.22	6.27	5.07	4.05	3.80	3.87	3.70	.....
27	.....	4.05	3.85	4.65	9.35	6.27	4.97	4.00	3.87	3.87	3.65	.....
28	.....	4.03	3.80	4.63	9.80	6.12	4.92	4.00	3.82	3.85	3.60	5.00
29	.....	.....	3.70	4.43	10.15	6.05	4.85	3.95	3.80	3.85	3.70	5.00
30	.....	.....	3.48	4.50	10.18	5.95	4.82	3.90	3.97	3.80	3.80	5.00
31	(a)	.....	3.53	.....	9.80	.....	4.75	3.90	.....	3.83	.....	5.00

a Ice at gage.

Rating table for Missoula River at Missoula, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.4	1,525	5.2	3,610	7.0	7,695	8.8	12,850
3.6	1,650	5.4	4,010	7.2	8,200	9.0	13,475
3.8	1,780	5.6	4,435	7.4	8,750	9.2	14,120
4.0	1,940	5.8	4,875	7.6	9,250	9.4	14,725
4.2	2,115	6.0	5,325	7.8	9,810	9.6	15,425
4.4	2,320	6.2	5,790	8.0	10,400	9.8	16,125
4.6	2,570	6.4	6,230	8.2	11,000	10.0	16,825
4.8	2,870	6.6	6,740	8.4	11,610		
5.0	3,240	6.8	7,205	8.6	12,250		

Estimated monthly discharge of Missoula River at Missoula, Mont.

[Drainage area, 5,960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
rch	1,900	1,580	1,766	108,587	0.30	0.35
ril	3,050	1,715	2,383	141,798	.40	.45
y	17,350	2,787	10,236	629,387	1.72	1.98
ne	15,775	5,212	8,852	526,771	1.49	1.66
y	6,975	2,787	4,725	290,529	.79	.91
gust	2,637	1,865	2,136	131,338	.36	.42
tember	1,865	1,715	1,778	105,798	.30	.33
tober	1,980	1,750	1,808	111,170	.30	.35
vember	2,215	1,650	1,875	111,570	.31	.35
cember, 14 days			2,236	62,091	.38	.20

BITTERROOT RIVER NEAR GRANTSDALE, MONT.

This station was established April 25, 1902, by H. B. Waters. It ocated on the highway bridge 2 miles southwest of Grantsdale and niles southwest of Hamilton, Mont. The gage is the usual wire e fastened to the downstream truss of the bridge. It is graduated feet and tenths and is read daily by T. J. Holt who lives about a arter of a mile north of the gage. The stream at this section is aight and has a moderate velocity. The right bank has a gentle pe and is liable to overflow. The left bank is high and rocky. The l of the stream is composed of gravel and bowlders. Bench mark . 1 is a wire nail driven in the northeast side of a large pine stump l marked B. M. 24.40. The stump is across the road from the st end of the bridge. The elevation above the zero of the gage, 40 feet. Bench mark No. 2 is the northwest bolt in the northwest atment plate of the bridge. It is marked B. M. 19.36. Its eleva- n above the zero of the gage is 19.36 feet.

Discharge measurements of Bitterroot River near Grantsdale, Mont.

Date.	Hydrographer.	Gage height.	Disch
1902.		*Feet.*	*Secon*
April 25	H. B. Waters	2.57	
Do	do	2.55	
July 11	do	3.38	
August 26	do	1.50	
Do	do	1.50	
November 29	J. S. Baker	1.72	

Daily gage height, in feet, of Bitterroot River near Grantsdale, Mont.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1		2.50	5.80	3.50	2.30	1.40	1.40	1.60
2		2.60	5.60	3.40	2.30	1.30	1.40	
3		2.50	5.00	3.70	2.20	1.30	1.40	
4		2.40	4.90	3.70	2.20	1.30	1.50	
5		2.40	4.70	4.00	2.10	1.20	1.50	
6		2.50	4.50	3.80	2.10	1.20	1.50	
7		2.80	4.50	3.70	2.00	1.10	1.50	
8		3.30	4.70	3.50	2.00	1.10	1.60	
9		4.00	5.50	3.30	1.90	1.10	1.60	1.80
10		4.60	6.30	3.40	1.90	1.20	1.60	1.80
11		4.80	5.70	3.50	1.90	1.20	1.60	1.80
12		5.00	5.40	3.60	1.90	1.10	1.60	1.80
13		5.20	5.20	3.50	1.80	1.10	1.50	1.70
14		5.80	5.00	3.40	1.80	1.10	1.40	1.70
15		6.20	4.70	3.30	1.80	1.10	1.40	1.70
16		6.00	4.50	3.30	1.80	1.20	1.40	1.70
17		5.40	4.30	3.20	1.80	1.20	1.40	1.70
18		4.90	4.40	3.20	1.80	1.30	1.50	1.70
19		4.50	4.00	3.10	1.80	1.20	1.50	1.70
20		4.10	4.00	3.00	1.80	1.30	1.50	1.70
21		3.90	4.00	3.00	1.70	1.30	1.50	1.70
22		3.80	4.10	3.00	1.70	1.30	1.60	1.70
23		3.80	4.50	2.90	1.70	1.30	1.60	2.00
24		4.00	4.60	2.90	1.60	1.40	1.50	2.10
25	2.50	4.20	4.30	2.80	1.60	1.40	1.50	1.60
26	2.60	4.50	4.10	2.80	1.60	1.40	1.50	1.60
27	2.60	5.50	4.00	2.70	1.50	1.40	1.50	1.60
28	2.60	6.20	3.90	2.60	1.50	1.40	1.50	1.60
29	2.50	6.80	3.80	2.50	1.50	1.40	1.50	1.70
30	2.50	6.20	3.70	2.50	1.40	1.30	1.50	1.70
31		6.00		2.40	1.40		1.60	

Rating table for Bitterroot River near Grantsdale, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	125	2.4	900	3.8	3,255	5.2	6,380
1.2	150	2.6	1,150	4.0	3,700	5.4	6,855
1.4	205	2.8	1,430	4.2	4,140	5.6	7,325
1.6	280	3.0	1,745	4.4	4,575	5.8	7,790
1.8	395	3.2	2,085	4.6	5,005	6.0	8,340
2.0	530	3.4	2,450	4.8	5,440	6.2	8,970
2.2	700	3.6	2,850	5.0	5,900		

Estimated monthly discharge of Bitterroot River near Grantsdale, Mont.

[Drainage area, 1,550 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April 25-30	.....	.....	1,085	12,912	0.70	0.16
May	11,075	900	4,823	296,555	3.11	3.59
June	9,285	3,050	5,176	307,993	3.34	3.73
July	3,700	900	2,143	131,768	1.38	1.59
August	790	205	428	26,316	.28	.32
September	205	135	167	9,937	.11	.12
October	280	205	242	14,879	.16	.18
November	615	280	353	21,005	.23	.26
December	1,150	340	472	29,022	.30	.35

PALOUSE RIVER NEAR HOOPER, WASH.

For some distance above Hooper, Palouse River consists of a succession of deep pools, from 10 to 15 feet in depth, connected by short riffles. Its valley is about one-half mile in width and bordered with basaltic cliffs approximately 300 feet in height.

The measurements of Palouse River are of value in showing the amount of water that could be utilized for irrigation on the lands of Washtucna Valley, and in the section north of Pasco. The gaging station was established April 1, 1897, by the land department of the Northern Pacific Railroad. September 9, 1897, the Geological Survey took charge of the station, placing the gage rod 1 mile below the former location and opposite the water tank, and stretching a cable across the river for discharge measurements. The rod is inclined, and fastened

to posts driven into the right bank. The bench mark is a point of rock, marked with red paint, on a ledge on the left bank of the river opposite the gage, and its elevation is 7.60 feet above datum. When the new gage reads 2.1 feet the height on the Northern Pacific Railroad gage is 6.1 feet. The channel is gravelly and not liable to change. The left bank is high and can not overflow. The right bank overflows at extreme high water. The initial point for sounding is the cable post on the left bank. The station is about 3 miles above the mouth of Cow Creek, and 2 miles below the head of the ditch of the Palouse Irrigation Company, carrying 25 second-feet when full. No measurements were made during 1901, the rating table for 1900 being used for that year. The 1902 table gives larger discharges, and it is probable that the discharges as published for 1901 are too small.

The following discharge measurements were made during 1902:

July 10: Gage height, 3.80 feet; discharge, 532 second-feet.
November 6: Gage height, 0.85 foot; discharge, 71 second-feet.

Daily gage height, in feet, of Palouse River near Hooper, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.30	1.60	5.80	3.00	2.70	3.20	1.35	1.20	0.60	0.70	0.75	1.60
2	2.25	1.50	5.50	2.90	2.70	3.00	1.35	1.20	.60	.70	.80	1.65
3	2.15	1.50	5.30	2.90	2.65	3.00	1.30	1.20	.60	.75	.85	3.30
4	2.20	1.50	5.05	3.00	2.65	3.00	1.40	1.20	.60	.80	.85	3.00
5	2.25	1.60	4.60	3.20	2.65	2.70	1.60	1.20	.60	.80	.85	2.90
6	2.20	1.80	4.30	3.40	3.40	2.60	1.80	1.20	.60	.80	.85	3.90
7	2.50	2.10	4.20	3.40	3.40	2.40	4.90	1.20	.60	.80	1.00	3.30
8	2.90	2.50	4.20	3.70	3.30	2.40	4.30	1.20	.60	.75	1.00	3.05
9	3.50	2.50	4.00	3.80	3.25	2.40	3.30	1.20	.55	.75	1.15	2.80
10	3.70	3.80	4.30	4.10	3.10	2.40	2.70	1.15	.55	.70	1.30	5.20
11	4.00	4.50	4.30	4.20	3.00	2.30	2.50	1.10	.55	.70	2.30	5.50
12	3.60	4.40	4.50	3.80	3.00	2.10	2.40	1.10	.55	.70	2.60	5.10
13	3.30	4.75	4.30	3.60	2.90	2.00	2.20	1.05	.55	.70	2.20	4.80
14	3.10	4.60	4.50	3.40	2.80	1.90	2.00	1.05	.55	.75	2.00	3.50
15	3.00	4.40	4.40	3.30	2.75	1.90	1.90	1.00	.50	.75	1.80	3.30
16	2.90	4.70	4.20	3.20	2.60	1.80	1.85	.95	.50	.75	1.70	3.00
17	2.80	5.60	4.20	3.00	2.50	1.80	1.85	.95	.50	.75	1.60	2.60
18	2.60	7.00	4.10	3.00	2.50	1.80	1.80	.90	.50	.75	1.60	2.10
19	2.40	7.70	4.00	3.00	2.40	1.60	1.80	.85	.55	.75	2.10	2.10
20	2.20	7.50	3.80	3.20	2.60	1.60	1.70	.85	.55	.75	2.70	2.20
21	2.15	7.00	3.70	3.30	2.80	1.60	1.65	.80	.55	.75	2.65	2.20
22	2.10	6.30	3.60	3.60	3.70	1.50	1.50	.75	.55	.75	2.45	2.20
23	2.10	5.60	3.60	3.60	5.90	1.50	1.50	.70	.55	.75	2.20	2.20
24	2.05	5.30	3.60	3.40	6.40	1.50	1.45	.70	.55	.75	2.10	2.20
25	2.00	5.10	3.50	3.30	6.30	1.40	1.45	.70	.60	.75	1.80	2.20
26	1.90	5.00	3.50	3.10	5.40	1.40	1.40	.70	.60	.75	1.80	2.70
27	1.80	5.80	3.40	3.00	4.60	1.40	1.40	.70	.60	.80	1.70	4.60
28	1.75	6.00	3.30	2.90	4.00	1.40	1.40	.70	.60	.85	1.70	4.40
29	1.70	.....	3.10	2.80	3.70	1.40	1.40	.65	.65	.80	1.70	4.10
30	1.60	.....	3.10	2.80	3.40	1.40	1.30	.65	.70	.75	1.60	3.90
31	1.60	.....	3.00	.....	3.30	.....	1.25	.65	.....	.75	.....	3.70

Rating table for Palouse River near Hooper, Wash., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.6	63	2.2	150	3.8	535	6.0	1,835
.8	69	2.4	175	4.0	625	6.5	2,150
1.0	75	2.6	205	4.2	725	7.0	2,465
1.2	85	2.8	240	4.4	835	7.5	2,780
1.4	95	3.0	280	4.6	953	8.0	3,095
1.6	106	3.2	325	4.8	1,079		
1.8	118	3.4	380	5.0	1,205		
2.0	130	3.6	455	5.5	1,520		

Estimated monthly discharge of Palouse River near Hooper, Wash.

[Drainage area, 2,210 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
nuary	625	106	216	13,281	0.10	0.12
›bruary	2,906	100	1,088	60,424	.49	.51
arch	1,709	280	716	44,025	.32	.37
pril	725	240	370	22,076	.17	.19
lay	2,087	175	515	31,666	.23	.27
une	325	95	150	8,926	.07	.08
uly	1,142	87	178	10,945	.08	.09
ugust	85	64	75	4,612	.03	.03
eptember	66	60	62	3,689	.03	.03
ctober	70	66	67	4,181	.03	.03
lovember	220	67	118	7,081	.05	.06
ecember	1,520	106	452	27,792	.20	.23
The year	2,906	60	334	238,698	.15	2.01

WEISER RIVER NEAR WEISER, IDAHO.

The drainage basin of this river is mountainous and rocky, in con-ast to the well-wooded areas of the Boise and Payette basins, and e effect is shown in the high flood discharges and low summer flow. number of small ditches utilize considerable water from this river, it the principal canal is the Galloway canal, which irrigates lands orth of Weiser. Above this canal is a bench country susceptible of ltivation if water could be brought to it. The gaging station, estab-shed December 6, 1894, is located in the canyon of the river, about 10

miles from Weiser. The gage rod which was set in 1898 was covered during the process of grading for the roadbed of the new Pacific and Idaho Northern Railroad, a line intended to run from Weiser to the mining country in the mountainous district to the north. The new gage, located on October 31, 1899, 100 feet above the old one, is inclined and bolted to a rock bluff; 1.15 feet along the gage equals one foot in elevation. The bench mark consists of a cross cut in the top of the lava rim rock above the gage, and is at an elevation of 12.90 feet. The elevation of the zero of the gage taken from the levels of the railroad is 2,191.34 feet above sea level. Discharge measurements are made from a cable and car about 300 feet below the gage. Both banks are high and not liable to overflow. The bed of the river is of gravel and not likely to change.

The following discharge measurements were made during 1902:

June 26: Gage height, 2.20 feet; discharge, 871 second-feet.
July 19: Gage height, 1.20 feet; discharge, 310 second-feet
August 4: Gage height, 0.40 foot; discharge, 53 second-feet.
September 18: Gage height, 0.30 foot; discharge, 56 second-feet.

Daily gage height, in feet, of Weiser River near Weiser, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.20	1.20	4.80	1.95	3.15	3.90	1.80	0.50	0.25	0.50	0.80	1.20
2	1.20	1.15	4.30	2.00	3.10	3.80	1.70	.45	.25	.50	.80	1.20
3	1.20	1.10	4.00	2.20	3.00	3.50	1.60	.40	.25	.50	.80	1.20
4	1.35	1.10	3.80	2.40	2.85	3.30	1.50	.40	.25	.50	.80	1.20
5	1.35	1.30	3.55	2.50	2.75	3.20	1.70	.40	.25	.50	.85	1.20
6	1.45	1.60	3.40	2.70	2.80	3.20	1.90	.35	.25	.55	.85	1.25
7	1.65	2.00	3.20	2.90	2.95	3.20	2.10	.35	.20	.55	.90	2.20
8	1.80	2.60	3.10	3.60	3.60	3.30	2.10	.35	.20	.55	1.00	2.50
9	1.75	5.60	3.10	3.90	3.65	3.40	2.00	.30	.20	.55	1.10	2.60
10	1.70	7.40	3.00	3.20	4.45	3.70	1.90	.30	.25	.55	1.10	2.80
11	1.65	7.40	2.90	3.00	4.10	3.60	1.80	.25	.30	.60	1.10	3.30
12	1.60	4.50	2.80	3.00	4.15	3.50	1.70	.20	.25	.60	1.10	3.40
13	1.55	3.80	2.60	2.90	4.20	3.40	1.65	.20	.25	.60	1.10	3.00
14	1.50	3.30	2.55	3.00	4.35	3.30	1.60	.20	.25	.60	1.15	2.80
15	1.45	4.30	2.50	3.20	4.30	3.00	1.50	.25	.25	.60	1.15	2.70
16	1.40	4.30	2.50	3.30	4.25	2.90	1.40	.40	.30	.60	1.15	2.50
17	1.40	4.35	2.45	3.45	4.00	2.80	1.30	.45	.30	.60	1.20	2.00
18	1.35	4.40	2.40	3.50	3.90	2.60	1.30	.65	.30	.60	1.20	1.90
19	1.30	3.90	2.30	3.85	3.50	2.50	1.20	.60	.30	.60	1.20	1.80
20	1.30	3.85	2.20	4.20	3.20	2.50	1.15	.55	.35	.60	1.20	1.70
21	1.25	3.55	2.20	4.00	3.10	2.40	1.10	.50	.35	.65	1.20	1.60
22	1.20	3.30	2.25	3.80	3.20	2.40	1.00	.50	.35	.65	1.20	1.60
23	1.20	3.25	2.30	3.80	3.20	2.30	.90	.50	.40	.65	1.20	1.50
24	1.20	5.40	2.30	3.70	3.10	2.20	.85	.45	.40	.70	1.20	1.60
25	1.35	7.30	2.25	3.60	3.20	2.10	.80	.40	.40	.70	1.20	2.00
26	1.35	7.20	2.25	3.50	3.30	2.10	.80	.40	.45	.70	1.20	2.20
27	1.45	6.00	2.20	3.40	3.60	2.05	.75	.35	.50	.75	1.20	3.00
28	1.65	5.90	2.20	3.00	4.10	2.00	.70	.30	.50	.75	1.20	2.80
29	1.50	.....	2.10	3.00	4.20	1.90	.65	.30	.50	.75	1.20	2.70
30	1.40	.....	2.00	3.10	4.10	1.85	.60	.25	.50	.80	1.20	2.50
31	1.30	.....	2.10	.....	4.00	.....	.55	.25	.....	.80	.....	2.40

Rating table for Weiser River near Weiser, Idaho, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	39	2.0	720	3.8	2,585	5.6	5,015
.4	71	2.2	875	4.0	2,855	5.8	5,285
.6	105	2.4	1,050	4.2	3,125	6.0	5,555
.8	150	2.6	1,235	4.4	3,395	6.2	5,825
1.0	215	2.8	1,425	4.6	3,665	6.4	6,095
1.2	290	3.0	1,625	4.8	3,935	6.6	6,365
1.4	375	3.2	1,840	5.0	4,205	6.8	6,635
1.6	470	3.4	2,075	5.2	4,475	7.0	6,900
1.8	585	3.6	2,325	5.4	4,745	7.2	7,170

Estimated monthly discharge of Weiser River near Weiser, Idaho.

[Drainage area, 1,670 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
1902.						
January	585	290	388	23,857	0.23	0.27
February	7,340	250	3,086	171,388	1.85	1.93
March	3,935	720	1,456	89,526	.87	1.00
April	3,125	685	1,886	112,225	1.13	1.26
May	3,463	1,378	2,354	144,742	1.41	1.63
June	2,720	618	1,546	91,993	.93	1.04
July	795	96	384	23,611	.23	.27
August	115	39	68	4,181	.04	.05
September	87	39	58	3,451	.03	.03
October	150	87	110	6,764	.07	.08
November	290	150	248	14,757	.15	.17
December	2,075	290	918	56,446	.55	.63
The year	7,340	39	1,042	742,941	.62	8.36

BOISE RIVER NEAR BOISE, IDAHO.

The station, established December 15, 1894, is located about 9 miles above Boise, Idaho, at the mouth of the canyon. The original gage was in two sections: The lower part is of 2 by 6 inch plank, inclined, and marked from 1 foot to 7.5 feet; the upper part is a 4 by 4 inch timber, placed vertically, and marked from 7.5 to 12 feet, both portions painted white. The bench mark for it was a bridge spike driven into a cottonwood tree 20 feet from gage and 20 feet from river. Wi-

miles from Weiser. The gage rod which was set in 1898 was cov during the process of grading for the roadbed of the new Pacific Idaho Northern Railroad, a line intended to run from Weiser to mining country in the mountainous district to the north. The gage, located on October 31, 1899, 100 feet above the old one, is incli and bolted to a rock bluff; 1.15 feet along the gage equals one foo elevation. The bench mark consists of a cross cut in the top of lava rim rock above the gage, and is at an elevation of 12.90 feet. elevation of the zero of the gage taken from the levels of the railr is 2,191.34 feet above sea level. Discharge measurements are m from a cable and car about 300 feet below the gage. Both banks high and not liable to overflow. The bed of the river is of gravel a not likely to change.

The following discharge measurements were made during 1902:

June 26: Gage height, 2.20 feet; discharge, 871 second-feet.
July 19: Gage height, 1.20 feet; discharge, 310 second-feet
August 4: Gage height, 0.40 foot; discharge, 53 second-feet.
September 18: Gage height, 0.30 foot; discharge, 56 second-feet.

Daily gage height, in feet, of Weiser River near Weiser, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1902.												
1	1.20	1.20	4.80	1.95	3.15	3.90	1.80	0.50	0.25	0.50	0.80	
2	1.20	1.15	4.30	2.00	3.10	3.80	1.70	.45	.25	.50	.80	
3	1.20	1.10	4.00	2.20	3.00	3.50	1.60	.40	.25	.50	.80	
4	1.35	1.10	3.80	2.40	2.85	3.30	1.50	.40	.25	.50	.80	
5	1.35	1.30	3.55	2.50	2.75	3.20	1.70	.40	.25	.50	.85	
6	1.45	1.60	3.40	2.70	2.80	3.20	1.90	.35	.25	.55	.85	
7	1.65	2.00	3.20	2.90	2.95	3.20	2.10	.35	.20	.55	.90	
8	1.80	2.60	3.10	3.60	3.60	3.30	2.10	.35	.20	.55	1.00	
9	1.75	5.60	3.10	3.90	3.65	3.40	2.00	.30	.20	.55	1.10	
10	1.70	7.40	3.00	3.20	4.45	3.70	1.90	.30	.25	.55	1.10	
11	1.65	7.40	2.90	3.00	4.10	3.60	1.80	.25	.30	.60	1.10	
12	1.60	4.50	2.80	3.00	4.15	3.50	1.70	.20	.25	.60	1.10	
13	1.55	3.80	2.60	2.90	4.20	3.40	1.65	.20	.25	.60	1.10	
14	1.50	3.30	2.55	3.00	4.35	3.30	1.60	.20	.25	.60	1.15	
15	1.45	4.30	2.50	3.20	4.30	3.00	1.50	.25	.25	.60	1.15	
16	1.40	4.30	2.50	3.30	4.25	2.90	1.40	.40	.30	.60	1.15	
17	1.40	4.35	2.45	3.45	4.00	2.80	1.30	.45	.30	.60	1.20	
18	1.35	4.40	2.40	3.50	3.90	2.60	1.30	.65	.30	.60	1.20	
19	1.30	3.90	2.30	3.85	3.50	2.50	1.20	.60	.30	.60	1.20	
20	1.30	3.85	2.20	4.20	3.20	2.50	1.15	.55	.35	.60	1.20	
21	1.25	3.55	2.20	4.00	3.10	2.40	1.10	.50	.35	.65	1.20	
22	1.20	3.30	2.25	3.80	3.20	2.40	1.00	.50	.35	.65	1.20	
23	1.20	3.25	2.30	3.80	3.20	2.30	.90	.50	.40	.65	1.20	
24	1.20	5.40	2.30	3.70	3.10	2.20	.85	.45	.40	.70	1.20	
25	1.35	7.30	2.25	3.60	3.20	2.10	.80	.40	.40	.70	1.20	
26	1.35	7.20	2.25	3.50	3.30	2.10	.80	.40	.45	.70	1.20	
27	1.45	6.00	2.20	3.40	3.60	2.05	.75	.35	.50	.75	1.20	
28	1.65	5.90	2.20	3.00	4.10	2.00	.70	.30	.50	.75	1.20	
29	1.50	.....	2.10	3.00	4.20	1.90	.65	.30	.50	.75	1.20	
30	1.40	.....	2.00	3.10	4.10	1.85	.60	.25	.50	.80	1.20	
31	1.30	.....	2.10	.....	4.00	.....	.55	.25	.....	.80	.....	

Rating table for Weiser River near Weiser, Idaho, for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.2	39	2.0	720	3.8	2,585	5.6	5,015
.4	71	2.2	875	4.0	2,855	5.8	5,285
.6	105	2.4	1,050	4.2	3,125	6.0	5,555
.8	150	2.6	1,235	4.4	3,395	6.2	5,825
1.0	215	2.8	1,425	4.6	3,665	6.4	6,095
1.2	290	3.0	1,625	4.8	3,935	6.6	6,365
1.4	375	3.2	1,840	5.0	4,205	6.8	6,635
1.6	470	3.4	2,075	5.2	4,475	7.0	6,900
1.8	585	3.6	2,325	5.4	4,745	7.2	7,170

Estimated monthly discharge of Weiser River near Weiser, Idaho.

[Drainage area, 1,670 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
anuary	585	290	388	23,857	0.23	0.27
ebruary	7,340	250	3,086	171,388	1.85	1.93
larch	3,935	720	1,456	89,526	.87	1.00
pril	3,125	685	1,886	112,225	1.13	1.26
ay	3,463	1,378	2,354	144,742	1.41	1.63
ne	2,720	618	1,546	91,993	.93	1.04
ly	795	96	384	23,611	.23	.27
gust	115	39	68	4,181	.04	.05
ptember	87	39	58	3,451	.03	.03
tober	150	87	110	6,764	.07	.08
vember	290	150	248	14,757	.15	.17
cember	2,075	290	918	56,446	.55	.63
The year	7,340	39	1,042	742,941	.62	8.36

BOISE RIVER NEAR BOISE, IDAHO.

The station, established December 15, 1894, is located about 9 miles ove Boise, Idaho, at the mouth of the canyon. The original gage was two sections: The lower part is of 2 by 6 inch plank, inclined, and rked from 1 foot to 7.5 feet; the upper part is a 4 by 4 inch timber, ced vertically, and marked from 7.5 to 12 feet, both portions inted white. The bench mark for it was a bridge spike driven a cottonwood tree 20 feet from gage and 20 feet from river. It is

3.4 feet above the 8-foot mark on the gage. Measurements are made from a cable just below the gage.

In the latter part of July, 1895, it was decided to locate a secondary gage on Boise River to obtain the slope of the water surface. This was placed 425 feet below the old gage and carefully connected by means of a wye level. Both were referred to the same datum. At that time the lower end of the old gage was found to be warped and was corrected. A gage was also placed on the lower Boise in order to determine the water going by at the lowest stage during the irrigating season. The meter can generally be used by wading, but in high water measurements can be made from a wagon bridge.

April 18, 1897, the river cut into the right bank of the station, carrying out the cable and leaving the gage on a small island, so that the record after that date is unreliable. A temporary gage was therefore established May 12 at the Broadway Bridge, at Boise, and a record kept by it until June 17, when a new gage, which is now used, was again placed in the canyon 1 mile above the old location. The inclined rod is firmly attached to a cottonwood tree. The bench mark is a 20-penny spike in the upstream face of the 6 by 8 cable support, about 2 feet above the ground. Its elevation is 15 feet above datum. Two spikes in same post are 14 feet above datum. Discharge measurements are made from a cable and car 50 feet below the gage. An auxiliary cable for flood measurements is placed 117 feet above the main cable. At ordinary stages the channel is straight, both above and below the station. The banks are high and not liable to overflow. About 300 feet below the cable is a gravel bar, reducing the width of the river at low water to about one-third of the channel and forcing the entire flow against the south bank. The channel is liable to change during extreme high floods. During 1900 the New York Canal Company built a wing dam of timber and loose rock, headed about 150 feet below the station and extending from the north bank diagonally down and across the stream a distance of about 50 feet, in order to protect the north bank from erosion. The construction of this wing dam did not seem to interfere with the flow of the river at the station. During the year new cable supports were set and bench marks were carefully verified.

Discharge measurements of Boise River near Boise, Idaho.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
July 11	N. S. Dils	1.80	1,808
July 25	do	1.10	1,346
August 7	do	.70	899
August 13	do	.60	845
September 15	do	.33	610

Daily gage height, in feet, of Boise River near Boise, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
.....	1.00	1.20	1.70	1.35	3.20	4.70	2.25	0.90	0.45	0.45	0.50	0.80
.....	1.20	1.30	1.60	1.85	3.10	4.30	2.35	.80	.45	.45	.50	.80
.....	1.10	1.80	1.50	1.98	2.90	4.00	2.30	.70	.40	.42	.50	.90
.....	1.03	1.40	1.45	2.40	2.90	3.90	2.55	.70	.40	.42	.50	.95
.....	.95	1.30	1.40	2.40	2.90	3.85	2.20	.60	.35	.40	.55	.80
.....	1.00	1.30	1.40	2.40	3.10	3.80	2.10	.70	.35	.40	.60	.80
.....	1.00	1.25	1.40	3.00	3.30	3.85	2.00	.70	.33	.40	.70	.80
.....	1.03	1.80	1.40	3.40	4.30	4.15	1.90	.60	.30	.40	.82	.80
.....	1.00	2.00	1.40	2.80	4.60	4.55	1.90	.12	.30	.40	.85	.90
.....	.90	2.00	1.38	2.50	4.40	4.90	1.95	.20	.35	.40	.85	1.20
.....	.70	1.90	1.38	2.50	4.40	4.80	1.95	.30	.40	.40	.90	1.22
.....	.65	1.80	1.35	2.55	4.60	4.60	2.00	.60	.35	.40	.90	1.10
.....	.60	1.55	1.35	2.55	5.00	4.45	2.05	.65	.30	.40	.85	.85
.....	.70	1.30	1.30	2.50	5.00	4.20	1.95	.67	.35	.40	.80	.60
.....	.70	1.25	1.30	2.60	4.70	3.90	1.90	.68	.40	.40	.70	.40
.....	.85	1.20	1.30	3.20	4.70	3.50	1.85	.65	.35	.40	.60	.40
.....	.95	1.30	1.30	3.40	4.00	3.40	1.80	.60	.30	.40	.70	.40
.....	1.00	1.40	1.30	4.00	4.20	3.30	1.70	.60	.35	.40	.80	.48
.....	.95	1.35	1.30	4.20	4.00	3.30	1.70	.60	.40	.40	.80	.90
.....	.90	1.30	1.30	4.40	3.85	3.20	1.60	.55	.40	.40	.70	.95
.....	.85	1.20	1.40	4.00	3.70	3.10	1.50	.55	.40	.40	.65	.98
.....	.80	1.20	1.40	3.80	3.65	3.10	1.30	.52	.40	.45	.60	1.00
.....	.70	1.20	1.40	3.60	3.60	3.10	1.10	.50	.40	.50	.65	1.10
.....	.60	2.70	1.40	3.40	3.55	3.20	1.10	.50	.40	.60	.70	1.10
.....	.60	2.40	1.40	3.25	3.65	3.10	1.10	.50	.40	.70	.75	1.20
.....	.60	2.20	1.40	3.30	4.00	2.90	1.00	.45	.40	.70	.80	1.15
.....	.60	2.10	1.45	3.30	4.40	2.80	1.00	.45	.40	.65	.90	1.20
.....	.50	1.80	1.40	3.20	4.90	2.60	1.00	.45	.40	.60	.70	1.00
.....	.40	.....	1.40	3.10	5.20	2.55	1.00	.40	.40	.55	.70	.90
.....	.60	.....	1.40	3.20	5.10	2.45	1.00	.40	.45	.50	.75	.40
.....	1.00	.....	1.40	.....	5.00	.....	.90	.42	.....	.50	.....	.85

Rating table for Boise River at Boise, Idaho, for 1902.

ge ht.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
t.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2	575	1.6	1,610	3.0	3,365	4.4	6,396
4	695	1.8	1,800	3.2	3,740	4.6	6,844
6	830	2.0	2,000	3.4	4,156	4.8	7,292
8	970	2.2	2,220	3.6	4,604	5.0	7,740
0	1,115	2.4	2,460	3.8	5,052	5.2	8,188
2	1,270	2.6	2,730	4.0	5,500		
4	1,435	2.8	3,030	4.2	5,948		

Estimated monthly discharge of Boise River near Boise, Idaho.

[Drainage area, 2,450 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	1,270	695	989	60,811	0.40	0.46
February	2,880	1,270	1,615	89,692	.66	.69
March	1,705	1,350	1,433	88,112	.58	.67
April	6,396	1,392	3,559	211,775	1.45	1.62
May	8,188	3,190	5,701	350,541	2.33	2.69
June	7,516	2,528	4,786	284,787	1.95	2.18
July	2,662	1,040	1,721	105,820	.70	.81
August	1,040	530	798	49,067	.33	.38
September	728	635	682	40,582	.28	.31
October	900	695	735	45,193	.30	.35
November	1,040	760	907	53,970	.37	.41
December	1,270	695	1,024	62,963	.42	.48
The year	8,188	530	1,996	1,443,313	.81	11.05

SEEPAGE MEASUREMENTS IN BOISE VALLEY.

A series of measurements of the discharge of canals taking water from Boise River between Boise and Caldwell, Idaho, was made during August 11 to 15, 1902, by N. S. Dils, to determine the amount of seepage water returning to the river. These measurements were similar to those made in 1898, 1899, 1900, 1901, and which are published in the reports for those years.

ellaneous discharge measurements of Boise River and other streams in Boise Valley.

).	Stream.	Locality of heading or place of measurement.	Discharge.
			Sec.-feet.
11	Sebree canal	North side in Caldwell Canyon	0.0
11	Seibenberg Slough	do	.5
11	Boise River	Caldwell bridge	.7
11	Riverside canal	South side in Caldwell Canyon	23.5
11	Wastein Tenmile Creek	South side below Star	1.0
11	Strahorn canal	do	18.0
11	Boise River	Star bridge	21.6
12	Eureka canal	South side below Soldiers' Home	8.5
12	Phyllis canal	do	15.8
12	Settlers canal	South side above Soldiers' Home	114.3
12	Davis canal	do	30.8
12	McCarty canal	do	103.0
13	Jacobs canal	North side above Soldiers' Home	61.2
13	Ellis canal	do	12.1
13	Goodwin Mill or Penault canal	do	91.5
13	Boise River	At regular gaging station, near Boise	845.0
13	New York canal	South side at gaging station	79.5
13	Costin canal	South side above Soldiers' Home	3.0
13	Lamburger & Ryan	do	.8
13	Ridenbaugh canal	do	433.7
13	Paynne canal	do	11.1
13	Rossi Logging canal	do	118.0
13	Small ditch	do	1.1
13	Rossi waste	do	101.0
13	Electric Light Works waste	do	25.0
14	Waste Car Line Power House	North side above Soldiers' Home	39.7
14	Farmers' Union and Boise Valley canals.	North side at Soldiers' Home	93.8
14	Waste ditch	North side above Star	3.6
14	Waste in sand draw	do	1.0
14	Union canal	do	15.0
14	Dry Creek canal	do	14.8
14	Conway & Akin, 2 ditches	Eagle Island	12.0
14	Catlin & Macey, 2 ditches	do	6.5
14	Davis & Hart	do	14.0
14	Midleton Mill Slough	North side above Star	5.4
14	Midleton Canal Company canal	do	8.5
14	Pioneer canal	do	9.3
15	Midleton Water Company canal	North side below Star	10.4
15	Waste east of Midleton	do	3.0
15	Waste from Willow Creek	do	.1
15	Sebree River	At Caldwell Canyon, north side	16.0
15	Seibenberg Slough	do	.4
15	Boise River	Caldwell bridge	1.5
15	Riverside canal	At Caldwell Canyon, south side	1.0

Summary of seepage measurements made on Boise River, August 11–15, 1902.

	Visible supply.	Diverted.
	Sec.-feet.	*Sec.-feet.*
Boise River and New York canal at gaging station	924.5	
Diverted by canals, south side, between gaging station and Soldiers' Home		95.5
Diverted by canals, north side, between gaging station and Soldiers' Home		29.1
Return waste, south side, between gaging station and Soldiers' Home	126.0	
Return waste, north side, between gaging station and Soldiers' Home	39.7	
Total from gaging station to Soldiers' Home	1,090.2	1,153.4
Diverted by canals, south side, between Soldiers' Home and Star		24.3 85.5
Return waste, north side, between Soldiers' Home and Star	4.6	
Boise River at Star		21.6
Total from gaging station to Star	1,094.8	1,284.8
Gain from gaging station to Star	190.0	
Boise River at Star	21.6	
Diverted by canals, south side, between Star and Caldwell Canyon		18.0
Diverted by canals, north side, between Star and Caldwell Canyon		10.4
Return waste, south side, between Star and Caldwell Canyon	1.0	
Return waste, north side, between Star and Caldwell Canyon	3.1	
Diverted by canals, south side, at Caldwell Canyon		1.0
Diverted by canals, north side, at Caldwell Canyon		16.6
Boise River at Caldwell		1.5
Total from Star to Caldwell	25.7	47.3
Gain from Star to Caldwell	21.6	
Total diverted on south side of river to Caldwell		1098.6
Total diverted on north side of river to Caldwell		370.4
Total waste on south side of river to Caldwell	127.0	
Total waste on north side of river to Caldwell	47.4	
Boise River and New York canal at gaging station	924.5	
Boise River at Caldwell		1.5
Total from gaging station to Caldwell	1,098.9	1,310.5
Gain from gaging station to Caldwell	211.6	

BRUNEAU RIVER NEAR GRANDVIEW, IDAHO.

Systematic measurements on this river have been maintained immediately below the headworks of the canal system of the Owyhee Land and Irrigation Company, 10 miles east of Grandview, Idaho. There are two gages, one on the north and one on the south side of the river, each at the same elevation. The channel is straight, both above and below the station, the banks high and rocky, and the bed changing little, if any, the section being a good one with the exception that the velocity is very slight at low water.

Daily gage height, in feet, of Bruneau River near Grandview, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.65	1.45	1.75	1.75	2.50	3.90	2.20	1.50	1.25	1.55	1.70	1.75
2	1.65	1.45	1.75	1.75	2.50	3.90	2.20	1.50	1.25	1.50	1.75	1.80
3	1.65	1.45	1.75	1.75	2.50	3.75	2.20	1.45	1.25	1.50	1.75	1.80
4	1.65	1.45	1.75	1.80	2.45	3.70	2.20	1.45	1.30	1.50	1.75	1.85
5	1.70	1.50	1.75	1.85	2.40	3.55	2.15	1.45	1.30	1.50	1.75	1.85
6	1.70	1.55	1.70	1.90	2.35	3.45	2.15	1.45	1.30	1.50	1.75	1.85
7	1.70	1.60	1.70	2.00	2.35	3.35	2.10	1.45	1.30	1.50	1.75	1.90
8	1.70	1.65	1.75	2.15	2.35	3.40	2.50	1.40	1.34	1.50	1.75	1.90
9	1.70	1.70	1.70	2.70	2.70	3.45	2.00	1.40	1.30	1.50	1.80	1.90
10	1.65	1.70	1.70	2.75	2.80	3.50	1.95	1.35	1.30	1.55	1.80	1.90
11	1.65	1.70	1.70	2.60	3.55	3.00	1.40	1.35	1.30	1.55	1.80	1.90
12	1.60	1.70	1.70	2.30	3.35	3.75	1.25	1.35	1.30	1.50	1.80	1.95
13	1.60	1.65	1.70	2.35	3.30	3.65	1.80	1.35	1.30	1.50	1.80	1.95
14	1.60	1.65	1.70	2.40	3.35	3.50	1.80	1.35	1.30	1.50	1.80	1.85
15	1.55	1.70	1.75	2.40	3.45	3.40	1.80	1.30	1.30	1.55	1.80	1.85
16	1.55	1.70	1.75	2.35	3.40	3.25	1.80	1.30	1.30	1.55	1.80	1.75
17	1.55	1.70	1.75	2.40	3.35	3.15	1.80	1.30	1.35	1.55	1.80	1.75
18	1.60	1.70	1.75	2.65	3.25	3.00	1.80	1.30	1.40	1.55	1.85	1.75
19	1.60	1.70	1.75	2.75	3.20	2.90	1.75	1.30	1.40	1.55	1.85	1.75
20	1.60	1.70	1.70	3.00	3.10	2.90	1.70	1.25	1.45	1.55	1.85	1.75
21	1.60	1.70	1.70	3.20	3.00	2.70	1.70	1.25	1.55	1.60	1.85	1.75
22	1.60	1.70	1.70	3.10	3.00	2.60	1.70	1.25	1.50	1.60	1.80	1.75
23	1.60	1.75	1.75	2.90	2.95	2.55	1.70	1.25	1.55	1.65	1.80	1.75
24	1.60	1.75	1.75	2.75	2.90	2.55	1.65	1.25	1.55	1.65	1.80	1.75
25	1.60	1.80	1.75	2.60	2.90	2.50	1.60	1.25	1.55	1.65	1.75	1.75
26	1.53	1.80	1.75	2.55	2.90	2.45	1.55	1.25	1.55	1.70	1.75	1.90
27	1.50	1.80	1.75	2.50	3.00	2.45	1.50	1.25	1.60	1.70	1.75	1.90
28	1.45	1.80	1.75	2.55	3.15	2.40	1.50	1.25	1.55	1.70	1.75	1.85
29	1.45	.....	1.75	2.50	3.35	2.40	1.50	1.25	1.55	1.70	1.75	1.85
30	1.45	.....	1.75	2.50	3.55	2.35	1.50	1.25	1.55	1.70	1.75	1.75
31	1.45	.....	1.75	.....	3.70	.....	1.50	1.25	.....	1.70	.....	1.70

SNAKE RIVER AT MONTGOMERY FERRY, IDAHO.

Ten miles above the gaging station at Montgomery Ferry occurs a natural dam site, from which, as a starting point, surveys for canal lines have been run, covering the large extent of level country susceptible of irrigation on both sides of the river. Measurements at Montgomery Ferry show the amount of water available for irrigation purposes there, and also the amount that could be developed for power purposes at Shoshone Falls, about 45 miles below. The station, established August 5, 1895, is located at Montgomery Ferry, on the stage road from Minidoka to Albion. The gage is inclined and fastened to posts set in the ground. The bench mark is the head of a spike in the east post of the tool house, 1.2 feet above the ground and 52 feet west of the gage. Its elevation is 17.50 feet above gage datum. The letters "B. M." are marked in black paint on the post. The river is 800 feet wide at this section, with a hard gravel bottom not subject to change. When the station was visited by N. S. Dils on

October 14, 1899, a comparison was made of the gage rod with the bench mark, and it was found that the rod had moved to a considerable extent, due to the action of the quicksand on the inclined portion of the rod. The heights as recorded by the observer, as well as the discharge measurements, were corrected. The rod is inclined from zero to 6.5 feet, and is vertical above this latter elevation. The lower portion is fastened at various intervals to posts driven into the ground. Gage readings were not taken during 1900.

The station was reestablished May 1, 1901, and the gage read morning and evening for the remainder of the year. Part of the inclined gage rod which had been moved by quicksand was corrected August 9, 1901, and all previous gage readings were carefully adjusted to correspond with the present position of the rod.

The following discharge measurements were made during 1902:

September 8: Gage height, 1.00 foot; discharge, 2,333 second-feet.
October 27: Gage height, 2.20 feet; discharge, 4,229 second-feet.

Daily gage height, in feet, of Snake River at Montgomery Ferry, near Minidoka, Idaho.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	3.80	2.40	2.80	2.10	3.45	7.05	4.90	1.90	0.90	1.80	2.40	2.90
2	4.20	2.30	2.80	2.10	3.50	7.50	4.75	1.75	.90	1.90	2.40	3.00
3	3.80	2.30	2.70	2.10	3.60	7.60	4.70	1.60	.90	1.90	2.40	3.10
4	3.40	2.30	2.70	2.10	3.60	8.00	4.60	1.45	.90	1.90	2.40	3.20
5	3.20	2.40	2.70	2.10	3.60	7.60	4.60	1.30	1.00	1.90	2.40	2.95
6	2.90	2.55	2.60	2.10	3.60	7.15	4.60	1.20	1.00	1.90	2.40	2.65
7	2.40	2.85	2.50	2.20	3.60	6.75	4.70	1.10	.90	1.90	2.50	2.50
8	2.40	2.90	2.50	2.30	3.50	6.60	4.70	1.05	1.00	1.90	2.60	2.50
9	2.40	3.60	2.50	2.40	3.60	6.60	4.55	1.00	1.00	2.00	2.60	2.60
10	2.40	3.65	2.50	2.50	3.70	6.50	4.35	.90	1.00	2.00	2.60	2.75
11	2.40	3.90	2.40	2.60	4.00	6.65	4.10	.90	1.00	2.00	2.70	2.90
12	2.40	3.10	2.40	2.60	4.60	7.15	3.95	.90	1.00	2.00	2.80	3.00
13	2.40	2.70	2.40	2.60	5.10	7.60	3.75	.90	1.00	2.00	2.80	2.80
14	2.40	2.70	2.40	2.50	5.50	7.90	3.55	.90	1.10	2.00	2.80	2.55
15	2.30	2.70	2.40	2.40	5.85	7.95	3.35	.85	1.10	2.10	2.90	2.90
16	2.20	2.70	2.30	2.40	6.00	7.90	3.30	.80	1.10	2.10	2.90	3.15
17	2.20	2.70	2.30	2.30	6.45	8.00	3.20	.85	1.20	2.10	2.90	3.70
18	2.20	2.70	2.30	2.30	6.50	7.65	3.15	.90	1.20	2.20	2.90	3.15
19	2.20	2.70	2.30	2.20	6.90	7.35	3.15	.90	1.20	2.20	2.90	3.90
20	2.20	2.70	2.30	2.40	6.90	7.10	3.15	.90	1.30	2.20	2.90	3.80
21	2.20	2.70	2.20	2.55	6.40	6.95	2.95	.90	1.40	2.20	2.80	4.40
22	2.30	2.70	2.20	3.00	6.15	6.50	2.80	.90	1.30	2.20	2.80	4.30
23	2.30	2.70	2.30	3.35	5.85	5.95	2.65	.90	1.30	2.20	2.80	3.95
24	2.30	2.70	2.30	3.55	5.55	5.40	2.45	.90	1.40	2.20	2.70	3.45
25	2.40	2.60	2.30	3.60	5.45	5.15	2.35	.90	1.40	2.20	2.60	2.85
26	3.00	2.60	2.20	3.50	5.25	5.15	2.25	.90	1.60	2.20	2.50	2.70
27	3.10	2.80	2.20	3.45	5.30	5.20	2.15	.90	1.50	2.20	2.60	2.60
28	3.20	2.80	2.20	3.40	5.40	5.20	2.10	.90	1.60	2.20	2.70	2.70
29	3.00	.....	2.20	3.30	5.75	5.15	2.10	.90	1.70	2.30	2.75	2.90
30	2.70	.....	2.20	3.30	6.25	4.95	2.00	.90	1.80	2.30	2.90	3.40
31	2.40	.....	2.10	.....	6.70	.....	1.95	.90	.....	2.30	.....	5.25

SNAKE RIVER (NORTH FORK) NEAR ORA, IDAHO.

s station was established August 20, 1902, by N. S. Dils. It is ›d at the North Fork Bridge 2 miles south of Ora and 10 miles › St. Anthony, Idaho. A temporary vertical gage was set on the side of the first pier from the north shore, at which point the ıanent gage will be located. The observer is Mrs. Martha J.

The initial point for soundings is a bolt through the toe of the .ever on the north end of the lower side of the bridge. The e is 210 feet from toe to toe of cantilever. It consists of four , resting on three rock-filled crib piers. Measurements are made the lower side of this bridge. The channel is straight both › and below this station. The banks are high and do not over-

The bed of the stream is hard gravel, quite smooth, and not lia- › change.

e following discharge measurements were made during 1902:

August 20: Gage height, 2.00 feet; discharge, 1,241 second-feet.
September 29: Gage height, 2.00 feet; discharge 1,244 second-feet.

ıily gage height, in feet, of Snake River (North Fork) near Ora, Idaho.

Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
					1902.					
.....	2.00	2.00	2.10	1.90	17	.....	2.00	2.00	2.10	1.90
.....	2.00	2.00	2.00	1.90	18	.....	2.00	2.00	2.10	1.90
.....	2.00	2.00	2.00	1.90	19	.....	2.00	2.00	2.00	1.10
.....	2.00	2.00	2.00	1.90	20	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	1.90	21	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	1.90	22	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	1.90	23	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	1.90	24	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	2.00	25	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	2.00	26	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.00	2.00	27	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.10	2.00	28	2.00	2.00	2.00	1.90	2.00
.....	2.00	2.00	2.10	2.00	29	2.00	2.00	2.10	1.90	2.00
.....	1.90	2.00	2.10	2.00	30	2.00	2.00	2.10	1.90	2.00
.....	2.00	2.00	2.10	2.00	31	2.00	.....	2.10	.....	2.00
.....	2.00	2.00	2.10	2.00						

'ALL RIVER AT WILSON'S MILL, NEAR MARYSVILLE, IDAHO.

is station was established August 21, 1902, by N. S. Dils. It is ›d at P. Wilson's sawmill, 12 miles southeast of Marysville, ›. The gage is a plain staff graduated to feet and tenths and is ' spiked to the lower side of the first bent from the south shore. :ead by P. Wilson, the owner of the mill. The initial point for lings is the face of the south abutment and measurements are from the bridge. The bridge rests on crib abutments. The is straight *both above and* below the station. The banks are *ınd not liable to overflow*. The bed of the river is hard gravel

with occasional lava bowlders. George Harringfield, a local civil engineer, states that the river in this vicinity has a fall of from 37½ to 39 feet per mile. The Harringfield canal is being built to divert the water from above this station.

The following discharge measurements were made during 1902:

August 21: Gage height, 2.00 feet; discharge, 916 second-feet.
October 1: Gage height, 1.90 feet; discharge, 857 second-feet.

Daily gage height, in feet, of Fall River near Marysville, Idaho.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.						1902.					
1	.....	1.90	1.90	1.80	1.80	17	.....	1.90	1.80	1.80	1.80
2	.....	1.90	1.90	1.80	1.80	18	.....	1.90	1.80	1.80	1.80
3	.....	1.90	1.90	1.80	1.80	19	.....	1.90	1.80	1.80	1.80
4	.....	1.90	1.90	1.80	1.80	20	.....	1.90	1.80	1.80	1.80
5	.....	2.00	1.90	1.80	1.80	21	.....	1.90	1.80	1.80	1.80
6	.....	2.00	1.90	1.80	1.80	22	.....	1.90	1.80	1.80	1.80
7	.....	1.90	1.90	1.80	1.80	23	.....	1.90	1.80	1.80	1.80
8	.....	1.90	1.90	1.80	1.80	24	2.00	1.90	1.80	1.80	1.80
9	.....	1.90	1.90	1.80	1.80	25	2.00	1.90	1.80	1.80	1.80
10	.....	1.90	1.90	1.80	1.80	26	2.00	1.90	1.80	1.80	1.80
11	.....	1.90	1.90	1.80	1.80	27	2.00	1.90	1.80	1.80	1.80
12	.....	1.90	1.90	1.80	1.80	28	2.00	1.90	1.80	1.80	1.80
13	.....	1.90	1.90	1.80	1.80	29	2.00	1.90	1.80	1.80	1.80
14	.....	1.90	1.90	1.80	1.80	30	2.00	1.90	1.80	1.80	1.80
15	.....	1.90	1.90	1.80	1.80	31	2.00	.....	1.80	.....	1.80
16	.....	1.90	1.80	1.80	1.80						

Miscellaneous measurements in Columbia River drainage basin.

Date.	Hydrographer.	Stream.	Locality.	Discharge.
1902.				
June 10, 11	N. S. Dils	All of the springs flowing into Snake River.	Between Shoshone Falls and the Cedars.	112
Aug. 7	do	New York canal	Near Boise gaging station	46
13	do	do	do	80
15	do	do	do	Dry.
25	do	Snake River	1 mile above mouth of Blackfoot River.	Dry.
27	do	Blue Lakes Creek	At Blue Lakes, Idaho	80
Sept. 1	do	Snake River	Between Shoshone Falls and Twin Falls.	1,987
25	do	Black Springs Creek	Near Ora gaging station	9
Nov. 28	J. S. Baker	Big Blackfoot	Bonner	4.0

PUGET SOUND DRAINAGE BASIN.

For convenience in arrangement the smaller rivers which have their headwaters on the western slope of the Cascade Range and which flow *into Puget Sound* north of Seattle have been grouped as the Puget *Sound drainage*. Of these White River has its source near Mount

inier and flows into Puget Sound near Seattle, Wash. Cedar ver is a tributary of White River. Snoqualmie and Skykomish 'ers unite to form the Snohomish, which flows into the Sound out 10 miles beyond the junction near Everett, Wash. The Stilquamish lies north of the Skykomish and has a parallel course. ıe following list includes the stations in the Puget Sound drainage sin:

White River at Buckley, Wash.
Cedar River near Maple Valley, Wash.
Cedar River at Cedar Lake, near Northbend, Wash.
Snoqualmie River above Snoqualmie Falls, near Snoqualmie, Wash.
Skykomish River (south fork) near Index, Wash.
Stilaguamish River near Robe, Wash.

WHITE RIVER AT BUCKLEY, WASH.

In order to determine the amount of power that could be developed White River, a station was established by Sydney Arnold, April ,1899, at the new highway bridge, 500 feet above the Northern Pacific ıilway bridge, and one-half mile north of the town of Buckley, Wash. ıe location is in sec. 34, T. 20 N., R. 6 E. of the Willamette meridian. ıe rod of the wire gage is fastened to the guard rail of the highway idge. The length of the wire rope is 20 feet. The elevation of the ɔ of the guard rail at the pulley is 19.56 feet above gage datum. The idge is a clear span of 180 feet, crossing the river a trifle obliquely. ıe channel is straight for some distance above and below the bridge, t the section is not a very good one, owing to the sudden fall a short stance below. About 300 feet above the bridge is a good section, th fine gravel bottom in calmer water, but in order to utilize it it ıuld be necessary to install a cable. An examination of the river annel for some distance above and below this point was made, but ɔ present location is about the only one available for accurate results. No measurements of discharge were made at this station during 1902.

Daily gage height, in feet, of White River at Buckley, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	1.15	0.85	1.15	0.80	1.30	1.95	1.95	1.40	0.85	0.70	0.65	4.23
2	1.20	.85	1.15	.80	1.30	1.80	2.10	1.35	.90	.65	1.15	2.70
3	1.35	.80	1.10	.95	1.65	1.75	1.90	1.30	1.00	.60	1.48	2.43
4	2.53	.75	1.10	1.10	1.60	1.70	2.15	1.20	.95	.60	1.15	2.93
5	2.25	.70	1.15	1.10	1.55	1.60	2.15	1.25	.80	.60	1.05	2.60
6	3.30	.70	1.15	1.00	1.70	1.60	1.55	1.30	.90	.55	.85	1.80
7	3.35	.70	1.15	1.50	2.05	1.60	1.80	1.45	1.00	.55	1.20	1.65
8	3.70	.75	1.20	1.40	2.15	1.80	1.75	1.45	.90	.60	2.73	2.10
9	2.85	.85	1.20	1.25	2.15	2.15	1.70	1.35	.85	.60	2.13	3.05
10	2.35	.85	1.20	1.15	2.55	2.15	1.80	1.20	.75	.60	1.70	2.40
11	2.10	.80	1.40	1.15	2.65	2.10	1.90	1.20	.75	.55	1.80	2.10
12	1.80	.75	1.35	1.15	2.40	2.05	1.80	1.15	.70	.60	1.65	1.80
13	1.65	.70	1.30	1.10	2.15	2.00	1.70	1.10	.70	.60	1.40	1.65
14	1.50	.70	1.20	1.10	2.15	2.00	1.70	1.10	.70	.65	1.25	1.65
15	1.45	1.30	1.15	1.05	2.20	1.95	1.80	1.10	.70	.65	1.20	1.50
16	1.35	2.80	1.10	1.15	2.20	1.80	1.90	1.10	.65	1.05	1.55	1.40
17	1.25	2.60	1.15	1.40	2.35	1.70	1.75	1.05	.65	.80	1.70	1.30
18	1.15	2.15	1.10	1.60	2.15	1.70	1.65	.95	.65	.65	1.85	1.25
19	1.15	1.80	1.10	2.15	2.00	1.80	1.65	.95	.85	.65	1.65	1.20
20	1.10	1.65	1.10	1.90	1.90	1.95	1.80	1.00	.60	.60	1.40	1.15
21	1.05	1.60	1.05	1.60	1.80	2.15	1.95	1.10	.50	.60	1.25	1.10
22	1.00	1.50	1.00	1.55	1.80	2.20	1.85	1.10	.50	.60	1.30	1.10
23	.90	1.40	1.00	1.50	1.95	2.35	1.70	1.05	.45	.55	1.30	1.05
24	.85	1.40	.95	1.40	1.95	2.60	1.60	1.00	.80	.55	1.50	1.88
25	.65	1.35	.95	1.35	2.05	2.60	1.60	.90	.75	.50	1.30	3.00
26	.90	1.30	.95	1.35	2.40	2.35	1.60	.90	.90	.50	1.30	3.43
27	.80	1.20	.90	1.35	3.00	2.15	1.50	.90	1.80	.50	1.20	2.60
28	.80	1.20	.90	1.35	3.10	1.95	1.45	.85	.95	.75	1.20	2.15
29	.90	.....	.90	1.30	2.75	1.85	1.35	.80	.80	.60	1.15	1.90
30	.90	.....	.85	1.30	2.40	1.95	1.30	.75	.90	.75	1.78	1.90
31	.90	.....	.85	.....	2.15	.....	1.50	.80	.....	.75	.....	1.90

CEDAR RIVER NEAR MAPLE VALLEY, WASH.

This station is located at the intake of the Seattle waterworks and is 15 miles below Cedar Lake, 4 miles from the Northern Pacific Railway at Ravensdale, and 6 miles from the Columbia and Puget Sound Railway at Maple Valley. The station was established September 27, 1902, by T. A. Noble. The gage is a plain staff graduated to feet and hundredths, to which is attached a hook gage and vernier reading to thousandths. When this gage reads zero the hook is level with the crest of the dam. It is fastened securely to the head gates above the dam, and is read daily by George Landsburg. The bench mark is the crest of the dam. The elevation, from city levels, of the south end is 535.831 feet and of the north end 535.840 feet. The gagings at this station are made at two points. The first is 142 feet below the dam where the cross section is small, the current rapid and suitable for gaging the stream at stages below 1 foot on the gage. The measurements at this point are made from a cable. The initial point for soundings is on the right bank; the channel is straight; the right bank is steep; the left bank has a sloping gravelly beach; and the bed of the stream is rocky. At all stages of the river above 1 foot on the

ge the measurements are made from a cable located 600 feet above dam, where the cross section is large and suitable for gaging the her stages of the river. The initial point for soundings is a spike ven into the top of a hemlock stump about 12 inches in diameter ar the water. The right bank is a sloping sandy beach; the left nk is steep and of hardpan formation. The bed is permanent—ky near the right bank and sand and gravel near the left bank.

To the discharge measurements made below the dam should be led the amount of water flowing into the gravity system which sup-es the city of Seattle. This varies from 34 to 37 second-feet. The scharge of this pipe line was measured during the winter of 1901–2, T. A. Noble, and the results have been published in Volume XLIX, ge 112, Transactions of the American Society of Civil Engineers. During 1902 the following discharge measurements were made by A. Noble.

September 28: Gage height, 0.88 feet: discharge, 435 second-feet.
October 22: Gage height, 0.38 feet; discharge, 124 second-feet.
November 23: Gage height, 1.31 feet; discharge, 755 second-feet.
December 25: Gage height, 1.74 feet; discharge, 1,043 second-feet.
December 26: Gage height, 2.04 feet; discharge, 1,399 second-feet.

Daily gage height, in feet, of Cedar River near Maple Valley, Wash.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
	1.53	0.92	1.35	1.01	1.32	1.56	1.05	0.68	0.47	0.70	0.63	3.28
	1.49	.92	1.18	1.05	1.39	1.55	1.12	.68	.53	.66	.70	3.08
	1.45	.90	1.18	1.05	1.68	1.51	1.14	.68	.53	.62	1.12	2.54
	1.90	.90	1.22	1.05	1.80	1.47	1.30	.66	.53	.58	1.22	2.40
	1.99	.90	1.30	1.05	1.76	1.39	1.55	.64	.53	.55	1.19	2.20
	2.36	.95	1.32	1.05	1.72	1.35	1.64	.62	.51	.52	1.10	1.85
	2.53	.95	1.39	1.07	1.80	1.35	1.68	.60	.51	.51	1.11	1.67
	2.86	.99	1.39	1.24	1.88	1.32	1.54	.60	.51	.52	1.00	1.47
	2.61	1.05	1.47	1.30	1.93	1.41	1.53	.58	.51	.50	1.90	1.91
	2.34	1.01	1.55	1.30	1.93	1.41	1.47	.58	.49	.48	1.83	1.83
	2.11	.97	1.68	1.26	1.93	1.41	1.39	.58	.49	.47	1.79	1.71
	1.90	.97	1.68	1.22	1.88	1.39	1.30	.55	.47	.46	1.83	1.58
	1.78	.97	1.55	1.18	1.84	1.32	1.28	.55	.45	.36	1.72	1.56
	1.65	.92	1.43	1.05	1.80	1.30	1.14	.53	.45	.36	1.55	1.45
	1.53	.91	1.35	1.01	1.84	1.22	1.05	.53	.43	.35	1.43	1.37
	1.40	1.39	1.35	.99	1.82	1.18	1.09	.53	.41	.36	1.42	1.27
	1.36	1.64	1.30	1.05	1.97	1.18	1.05	.60	.39	.35	1.58	1.22
	1.28	1.85	1.26	1.39	2.05	1.16	1.01	.58	.37	.40	1.85	1.15
	1.23	1.80	1.22	1.47	2.01	1.14	.99	.55	.47	.39	1.85	1.61
	1.11	1.60	1.22	1.55	1.89	1.09	.97	.55	.35	.35	1.69	1.60
	2.07	1.55	1.22	1.55	1.87	1.14	.93	.55	.33	.35	1.54	1.49
	2.03	1.51	1.26	1.53	1.84	1.09	.91	.53	.33	.38	1.42	1.73
	.99	1.43	1.28	1.51	1.76	1.14	.89	.53	.33	.65	1.34	1.30
	.97	1.35	1.24	1.47	1.80	1.12	.85	.53	.33	.62	1.36	1.36
	.97	1.30	1.22	1.43	1.72	1.12	.80	.51	.28	.56	1.32	1.66
	.97	1.30	1.18	1.39	1.68	1.09	.80	.51	.28	.52	1.28	2.03
	.97	1.35	1.14	1.35	1.66	1.09	.76	.49	1.01	.48	1.25	1.92
	.95	1.35	1.14	1.30	1.80	1.09	.74	.49	.88	.53	1.24	1.75
	.95	.....	1.09	1.32	1.88	1.05	.74	.47	.80	.53	1.23	1.69
	.95	.....	1.05	1.35	1.80	1.12	.72	.47	.70	.53	1.30	1.78
	.90	.....	1.18	.....	1.72	.....	.70	.47	.....	.61	.....	1.93

CEDAR RIVER AT CEDAR LAKE, NEAR NORTHBEND, WASH.

This station was established October 17, 1902, by T. A. Noble. It is located 9 miles southeast of Northbend, Wash. The gage is a plain staff graduated to feet and tenths. A hook and vernier are used for reading to hundredths. It is securely nailed to a large cedar stump. The bench mark is located on the stump which holds the gage. Its elevation is 1,542.07 feet above the datum of the city of Seattle, Wash. The initial point for soundings is a nail driven into the root of a hemlock stump on the right bank. The gagings are made from a cable. The channel is straight both above and below the station. The right bank is steep, high, and never overflows; the left bank is steep and overflows at extreme high water. The bed of the stream is rocky near the left bank, and of gravel and sand at the right bank. Underlying the bed is a formation of very compact hardpan, which shows no sign of washing away. This formation also underlies the river up to and including the lower portion of Cedar Lake, which is about 800 feet upstream from the gaging station. Cedar Lake contains about 1,200 acres at low water.

During 1902 the following discharge measurements were made by T. A. Noble:

October 17: Gage height, 2.21 feet; discharge, 245 second-feet.
October 18: Gage height, 1.70 feet; discharge, 112 second-feet.
October 18: Gage height, 2.17 feet; discharge, 217 second-feet.
October 19: Gage height, 1.13 feet; discharge, 84 second-feet.
October 19: Gage height, 1.49 feet; discharge, 89 second-feet.

Daily gage height, in feet, of Cedar River at Cedar Lake, Washington.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1	.....	2.04	8.65	12	.....	4.61	3.53	23	2.16	3.22	2.3
2	.....	2.38	7.60	13	.....	4.30	3.35	24	2.00	3.23	2.3
3	.....	3.01	6.35	14	.....	3.87	3.24	25	1.97	3.14	2.1
4	.....	3.12	5.58	15	.....	3.56	2.95	26	1.75	3.08	4.1
5	.....	2.98	4.94	16	.....	3.60	2.81	27	1.67	3.04	4.
6	.....	2.91	4.31	17	2.21	4.00	2.68	28	1.73	3.01	4.
7	.....	3.06	3.90	18	2.18	4.57	2.59	29	1.70	3.02	3.
8	.....	4.14	3.62	19	1.49	4.44	2.49	30	1.79	3.53	3.
9	.....	4.94	4.00	20	.....	4.03	2.44	31	1.95	.....	4.
10	.....	4.57	4.02	21	.....	3.67	2.37				
11	.....	4.59	3.95	22	2.40	3.41	2.37				

SNOQUALMIE RIVER ABOVE SNOQUALMIE FALLS, WASH.

This station was originally established by T. A. Noble on Septemb 14, 1902. The gage was then located below the falls, but was destroy by the flood of December 1, 1902. On November 2 another gage w placed about 3 miles above Snoqualmie Falls post-office. The ga consisted of a plain staff graduated to feet and tenths and reading

hundredths of a foot by means of a hook and vernier. The elevation of the zero on the gage was assumed to be 100 feet. The gage was fastened to an alder tree. January 3, 1903, this gage was washed out and on January 7 was replaced by a gage in two parts, 7 and 8 feet long, respectively. The elevation of the zero of the gage is 100.06 feet. The bench mark is on a large maple stump on the right bank. It consists of a spike driven into the stump about 4 feet from the ground. This is also the initial point for the soundings. The right bank is high and never overflows; the left bank overflows at extreme high water. The bed of the stream is of gravel and sand and is not liable to shift. The station is located below the junction of the North, South, and Middle forks of Snoqualmie River. At Snoqualmie Falls, about 4 miles below this station, the river flows over a precipice 268 feet high. Above the falls the Snoqualmie Falls Power Company has built a dam and water power plant. The slack water from this dam reaches back from the falls about 3 miles and probably affects the flow of the river slightly at the gaging station. This is the only possible location for a gaging station which will include all three forks of the river.

During 1902 the following discharge measurements were made by T. A. Noble:

[a] September 20: Gage height, 1.15 feet; discharge, 727 second-feet.
[a] October 14: Gage height, 1.04 feet; discharge, 641 second-feet.
[b] November 3: Gage height, 5.04 feet; discharge, 3,231 second-feet.
[b] December 14: Gage height, 3.37 feet; discharge, 1,888 second-feet.
[b] December 17: Gage height, 2.76 feet; discharge, 1,384 second-feet.

Daily gage height, in feet, of Snoqualmie River below Snoqualmie Falls, Washington.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.					1902.				
1	.....	1.80	2.45	(c)	12	.....	1.15	3.70	(c)	23	0.97	1.19	2.60	(c)
2	.....	1.60	4.02	.....	13	.....	1.10	3.15	.....	24	1.05	1.08	3.13	.....
3	.....	1.47	3.50	.....	14	0.95	.99	2.73	.....	25	1.39	1.04	2.70	.....
4	.....	1.45	3.00	.....	15	.93	1.09	2.60	.....	26	1.50	1.00	2.63	.....
5	.....	1.35	2.50	.....	16	.92	1.25	4.17	.....	27	3.80	.93	2.65	.....
6	.....	1.25	2.20	.....	17	.92	1.29	4.25	.....	28	2.60	1.62	2.64	.....
7	.....	1.22	2.23	.....	18	.90	1.20	3.85	.....	29	2.05	1.70	2.45	.....
8	.....	1.30	5.05	.....	19	1.50	1.10	3.13	.....	30	2.02	2.41	6.53	.....
9	.....	1.30	3.55	.....	20	1.19	1.10	2.73	.....	31	.....	2.75	.....	.....
0	.....	1.23	3.30	.....	21	1.06	1.08	2.47	.....					
1	.....	1.25	4.55	.....	22	1.00	1.18	2.73	.....					

[a] Below the falls. [b] Above the falls. [c] Gage washed out. Station removed above falls.

Daily gage height, in feet, of Snoqualmie River above Snoqualmie Falls, Washington.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1902.			1902.			1902.		
1	.....	15.00	12	5.99	3.84	23	3.82	2.82
2	.....	7.41	13	4.72	3.80	24	3.23	3.45
3	5.23	5.64	14	3.94	3.47	25	3.46	10.45
4	4.21	6.46	15	3.46	3.20	26	3.08	9.45
5	3.19	5.30	16	4.59	2.98	27	3.19	6.39
6	3.20	4.47	17	5.63	2.81	28	3.08	5.05
7	3.87	3.93	18	6.20	2.66	29	3.00	4.36
8	6.26	3.72	19	4.88	2.50	30	3.23	5.09
9	4.94	7.30	20	4.06	2.80	31	.....	5.83
10	5.38	5.24	21	3.59	2.90			
11	6.19	4.34	22	3.73	3.01			

SKYKOMISH RIVER (SOUTH FORK) NEAR INDEX, WASH.

This station was established October 6, 1902, by T. A. Noble. It is located about 2 miles above Index and about 300 feet from the railroad track. The gage is a plain staff graduated to feet and tenths. A hook and vernier are used for reading to hundredths of a foot. Readings are made daily by Louis G. Heybrook. The gage is fastened by means of plugs driven in drill holes in the solid rock. The bench mark is a cross cut in the rock about 6 feet above low water and 40 feet downstream from the gage. Its elevation as obtained from the Great Northern Railway is 679.158 feet. The elevation of the zero of the gage is 669.926 feet. The initial point for sounding is on the left bank at a plug driven in the solid rock 10 feet from the edge of stream at low water. The gagings are made from a cable. The channel is straight, both above and below the station. Both banks are of solid rock. The bed of the stream is of sand and gravel, not liable to change except near the left bank, where the sand shifts at high water. This does not cause any important change in the cross section. This station is 300 feet upstream from Sunset Falls, where the river plunges down a solid granite ledge with a slope of about two horizontal to one vertical. The ledge answers the purpose of a spillway in regulating the flow of the river at the gaging station, since the water has a free discharge and a permanent bed just below the station.

Daily gage height, in feet, of Skykomish (South Fork) River near Index, Wash.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1902.				1902.				1902.			
1		3.65	11.41	12	1.31	5.27	3.53	23	0.88	3.25	2.10
2		4.10	7.28	13	1.23	4.39	3.35	24	.99	3.69	2.50
3		4.70	5.65	14	1.21	3.76	3.10	25	.99	3.53	8.20
4		4.15	5.52	15	1.22	3.57	2.85	26	.91	3.26	8.59
5		3.54	4.82	16	1.31	4.72	2.65	27	.91	3.65	6.36
6		3.02	4.26	17	1.29	5.64	2.49	28	1.31	3.33	5.51
7	1.61	3.92	3.69	18	1.18	6.09	2.38	29	2.51	3.09	4.50
8	1.53	5.65	3.52	19	1.13	4.88	2.29	30	3.42	5.95	5.31
9	1.52	5.21	5.35	20	1.09	4.09	2.30	31	3.92		6.01
10	1.46	4.76	4.55	21	1.07	3.62	2.12				
11	1.39	5.85	4.03	22	.90	3.38	2.14				

Discharge measurements of Skykomish River (South Fork) near Index, Wash.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-feet.*
October 7	T. A. Noble	1.58	685
October 8	do	1.53	657
October 22	A. B. Carter	1.25	565
December 7	T. A. Noble	3.64	1,674
December 8	do	3.72	1,805
December 9	do	5.33	2,850
December 19	do	2.23	946

STILAGUAMISH RIVER NEAR ROBE, WASH.

This station was established December 3, 1902, by T. A. Noble. It is located at the bridge of the Everett and Monte Cristo Railway, 1½ miles east of Robe, Wash. The gage is a plain staff graduated to feet and tenths, and read by means of a hook gage and vernier to hundredths. It is fastened to the east bridge pier, and is read daily by Wm. A. Dobson. Arrangements will be made for gaging the river during the coming summer. The bench mark is the top of the rail above the east pier of the bridge. Its elevation is 901.06 feet above sea level. The elevation of the zero of the gage is 873.184 feet. The elevation of the bridge to which the gage is attached was furnished by the Everett and Monte Cristo Railway Company.

Daily gage height, in feet, of Stillaguamish River near Robe, Wash.

Day.	Dec.	Day.	Dec.	Day.	Dec.	Day.	Dec.
1902.		1902.		1902.		1902.	
1		9	8.40	17	1.56	25	9.91
2		10	8.50	18	1.33	26	6.39
3	3.54	11	9.10	19	1.40	27	4.21
4	3.92	12	8.30	20	2.28	28	3.06
5	2.85	13	2.48	21	1.84	29	7.67
6	2.30	14	1.07	22	1.96	30	5.29
7	3.40	15	1.87	23	1.78	31	3.77
8	8.40	16	1.56	24	4.61		

HUDSON BAY DRAINAGE BASIN.

Red River drains a large basin in the United States, covering portions of Minnesota and North and South Dakota, characterized by a level topography, broken up in places by moraines and other glacial deposits. The major part is prairie, and its eastern half has an abundance of lakes and some woods. The main river flows nearly due north, cutting a deep channel in its broad level valley and is subject to sudden rises caused by heavy spring rains, entailing frequently considerable loss of life and property. The valley of Red River comprises about 9,000,000 acres of excellent agricultural lands which to a large extent still await settlement. A number of water powers have been developed during recent years on the tributaries entering from both sides.

Red River drains into Hudson Bay through Lake Winnipeg and Nelson River. Red Lake River, one of its principal tributaries in Minnesota, drains Red Lake in the northern part of the State. Sheyenne River, its principal tributary from North Dakota, joins the Red River about 10 miles below Fargo, N. Dak.

St. Mary River heads in northern Montana, near the Canadian boundary line, on the eastern slope of the main range of the Rocky Mountains, in a region of perpetual snow and in the midst of numerous glaciers. It starts from the great Blackfoot Glacier (probably the largest in the Rocky Mountains within the United States) and receives affluents from at least a dozen lesser ones. These small streams unite within a short distance from their sources and flow into a lake hemmed in by high mountains, known as upper St. Mary Lake. Below this, separated by a narrow strip of land, is lower St. Mary Lake. The aggregate length of these two lakes is about 22 miles. The River flows out of the lower lake, the elevation of which is 4,460 feet above sea level, and within two miles is joined by a stream nearly, if not quite, as large as itself, known as Swiftcurrent Creek, which receives the water of the Grinnell Glacier and four lesser ones. From the confluence of these streams to the boundary of the British possessions, a distance of 12 miles, the river flows in a northerly direction. Enter-

; Alberta, it empties into Belly River, its waters at length finding ›ir way through Saskatchewan River into Hudson Bay. A canal s been constructed in Canada, by the Canadian Northwest Irriga- n Company, which diverts water from the right bank of St. Mary ver about 5 miles below the international boundary line.

The following list includes the stations of the Hudson Bay drainage sin:

St. Mary River at international line near Cardston, Alberta.
St. Mary River at Main, Mont.
Swiftcurrent Creek at Henkel's ranch near St. Mary, Mont.
St. Mary River at dam site near St. Mary, Mont.
Red River at Emerson, Manitoba.
Red Lake River at Crookston, Minn.
Red River at Grand Forks, N. Dak.
Sheyenne River at Haggart, N. Dak.
Red River at Fargo, N. Dak.
Devils Lake at Devils Lake, N. Dak

. MARY RIVER AT INTERNATIONAL LINE NEAR CARDSTON, ALBERTA.

This station was established October 11, 1902, by C. T. Prall. It is cated one-quarter mile north of the Montana line and 17 miles south Cardston, Alberta. The gage is of the usual wire type with the ıge board graduated to feet and tenths. The length from the bot- m of the weight to the marker is 10.85 feet. It is fastened to a tree ıd a post. The initial point for sounding is on the left bank. The ıannel is straight for 300 feet above and 150 feet below the station. he right bank is high and not liable to overflow. The left bank is ›ping and liable to overflow at very high water. The bed of the ream is of sand and gravel, but not liable to scour. The measure- ents are made from a car and cable. The observer is Vernon Shaw. ›nch mark No. 1 is a 60-penny spike driven in a cottonwood tree ated directly back of the rod. Its elevation is 12.92 feet above the o of the gage. Bench mark No. 2 is a 60-penny spike driven in a st 1 foot in diameter and 2 feet high. The post is set in the ground feet northwest of the gage rod. Its elevation is 17.56 feet above › zero of the gage.

The following discharge measurements were made during 1902:

October 11: Gage height, 3.90 feet; discharge, 501 second-feet.
October 23: Gage height, 3.65 feet; discharge, 387 second-feet.

Daily gage height, in feet, of St. Mary River at International line, near Cardston, Alberta.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.				
1	.....	4.00	3.45	3.65	17	4.00	3.95	3.65	5.15
2	.....	4.00	3.45	3.60	18	4.00	3.95	3.65	5.05
3	4.25	4.05	3.50	3.50	19	4.00	3.90	3.60	5.00
4	4.25	4.00	3.50	3.30	20	4.00	3.90	3.65	5.00
5	4.20	.....	3.50	3.60	21	4.10	3.90	3.65	5.00
6	4.10	.....	3.45	3.80	22	4.10	3.90	3.65	5.00
7	4.12	.....	3.45	3.80	23	4.00	3.65	3.65	4.60
8	4.10	.....	3.50	4.00	24	4.10	3.60	3.60	4.65
9	4.10	.....	3.60	4.00	25	4.00	3.60	3.65	5.00
10	4.10	.....	3.65	4.00	26	4.10	3.50	3.25	5.00
11	4.00	.....	3.65	4.20	27	4.00	3.50	3.35	4.80
12	4.00	3.85	3.70	5.20	28	4.00	3.50	3.00	4.75
13	4.00	3.90	3.65	5.00	29	4.10	3.50	3.20	4.70
14	4.00	4.00	3.65	5.20	30	4.00	3.45	3.60	4.65
15	3.11	3.95	3.60	5.20	31	.....	3.45	.....	.....
16	4.10	3.95	3.60	5.20					

ST. MARY RIVER AT MAIN, MONT.

This station was established by C. C. Babb, July 14, 1901, and is located at the highway bridge at Main, about 1 mile below the mouth of Swiftcurrent Creek. During 1900 a number of measurements were made at this point, and a temporary bench mark was established, consisting of a notch in the timber on the downstream side of the right abutment. When the station was established the height of this notch on the gage was found to be 1.60 feet. The rod is vertical and is spiked to the timbers on the lower end of the left abutment. Bench mark No. 1 is a nail in the blaze of a cottonwood tree 13 feet northwest of the rod, and is at an elevation of 4,418.49 feet. Bench mark No. 2 is a temporary bench mark of the topographic division, consisting of a stone in the road 400 feet northwest of the bridge, at an elevation of 4,419 feet. The elevation of the zero of the rod is 4,411.72. The channel above and below the station is straight, and the velocity of the water is swift. The right bank is high, and the left bank is low and liable to overflow. A short distance west of the bridge is a slough which carries some water during flood stages, and, therefore, has to be gaged on such occasions. The bed of the stream consists of gravel and bowlders. The station was discontinued November 1, 1902. Stations at Dam Site and at Henkel's ranch give the discharge at Main.

Discharge measurements of St. Mary River at Main, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 9	J. S. Baker	0.10	168
August 22	W. B. Freeman	1.50	944
September 2	do	1.11	661
September 22	C. T. Prall	.61	420
September 30	W. B. Freeman	.61	407
October 8	C. T. Prall	.57	402
October 17	do	.55	402
October 23	do	.35	311
October 30	do	.25	281

Daily gage height, in feet, of St. Mary River at Main, Mont.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.										
1	0.05	0.25	0.05	-0.05	0.70	4.40	3.40	2.25	1.25	0.30
2	.00	.25	.05	-.05	.75	4.20	3.70	2.15	1.15	.40
3	.00	.25	.05	-.05	.75	4.00	6.25	2.05	1.05	.40
4	.00	.25	.05	.00	.80	3.70	6.50	1.95	1.00	.40
5	.00	.25	.00	.00	.90	3.60	5.80	1.90	1.00	.30
6	-.10	.20	.00	.05	.95	3.40	5.00	1.90	1.00	.30
7	-.10	.20	.00	.05	1.00	3.30	4.80	1.90	1.00	.30
8	-.10	.20	.00	.10	1.10	3.30	4.00	1.90	1.00	.25
9	-.10	.20	.05	.10	1.30	3.40	3.60	1.95	.90	.25
10	-.15	.20	.05	.10	1.60	3.50	3.40	1.95	.90	.25
11	-.15	.15	.05	.15	1.80	3.50	3.20	1.95	.90	.20
12	-.15	.15	.10	.15	2.00	3.40	.....	1.90	.85	.20
13	-.10	.15	.10	.20	2.30	3.40	2.90	1.85	.85	.20
14	+.10	.15	.10	.20	2.80	3.30	2.80	1.80	.80	.25
15	.10	.10	.10	.20	3.10	3.40	2.70	1.75	.75	.20
16	.15	.10	.10	.30	3.40	3.30	2.60	1.70	.80	.20
17	.15	.10	.10	.40	3.80	3.20	2.60	1.70	.80	.20
18	.20	.10	.10	.40	3.90	3.10	2.50	1.70	.75	.25
19	.20	.10	.05	.50	3.60	3.00	2.40	1.65	.75	.....
20	.20	.10	.05	.50	4.20	2.90	2.30	1.60	.70	.....
21	.20	.05	.05	.50	5.00	2.80	2.40	1.65	.60	.....
22	.15	.05	.05	.55	4.50	3.10	2.40	1.60	.50	.....
23	.15	.05	.00	.55	4.40	3.10	2.50	1.50	.40	.....
24	.15	.05	.00	.60	4.50	3.10	2.50	1.50	.35	.....
25	.15	.05	.00	.60	4.40	3.10	2.60	1.50	.35	.....
26	.15	.05	.00	.65	4.30	3.30	2.60	1.50	.35	.....
27	.15	.05	-.05	.65	4.25	3.30	2.60	1.45	.30	.....
28	.15	.05	-.05	.65	4.35	3.30	2.60	1.45	.30	.....
29	.20	.....	-.05	.70	4.60	3.30	2.50	1.40	.30	.....
30	.20	.....	-.05	.70	4.80	3.40	2.45	1.35	.30	.....
31	.20	.....	-.05	.....	4.50	.....	2.35	1.30	.....	.....

Rating table for St. Mary River at Main, Mont.

FROM JANUARY 1 TO JUNE 30, 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
−1.4	41	0.8	415	3.0	2,422	5.2	5,106
−1.2	48	1.0	501	3.2	2,666	5.4	5,350
−1.0	57	1.2	587	3.4	2,910	5.6	5,594
− .8	70	1.4	673	3.6	3,154	5.8	5,838
− .6	87	1.6	790	3.8	3,398	6.0	6,082
− .4	108	1.8	960	4.0	3,642	6.2	6,326
− .2	137	2.0	1,202	4.2	3,886	6.4	6,570
.0	175	2.2	1,446	4.4	4,130	6.6	6,814
.2	220	2.4	1,690	4.6	4,374	6.8	7,058
.4	273	2.6	1,934	4.8	4,618		
.6	338	2.8	2,178	5.0	4,862		

FROM JUNE 30 TO DECEMBER 31, 1902.

−1.0	57	0.0	190	1.0	612	2.0	1,290
− .8	70	.2	257	1.2	720	[a] 2.2	1,446
− .6	87	.4	330	1.4	842		
− .4	108	.6	424	1.6	986		
− .2	143	.8	518	1.8	1,138		

[a] From this height the tables are the same.

Estimated monthly discharge of St. Mary River at Main, Mont.

[Drainage area, 298 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January	220	146	193	11,867	0.65	0.7
February	232	185	205	11,385	.69	.7
March	195	165	181	11,129	.61	.7
April	373	165	257	15,292	.86	.9
May	4,862	373	2,490	153,104	8.36	9.6
June	4,130	2,178	2,873	170,955	9.64	10.7
July	6,692	1,568	2,737	168,292	9.18	10.5
August	1,507	780	1,090	67,010	3.66	4.2
September	750	293	488	29,038	1.64	1.8
October 1 to 18			282	10,074	.95	.

SWIFTCURRENT CREEK AT HENKEL'S RANCH, NEAR ST. MARY, MONT.

This station was originally established April 8, 1902, by J. S. Baker, and was located one-half mile northwest of Henkel's ranch and 36 miles northwest of Browning, Mont. The nearest post-office is Wetzel. Henkel's ranch is reached by regular stage from Wetzel, Mont. The gage is of the usual wire type, with the gage rod graduated to feet and tenths. It is firmly nailed to a horizontal support, and is read daily by Henry Henkel. The initial point for sounding is on the left bank, and measurements are made from a cable and car. The channel is straight for 500 feet above and 200 feet below the station. The right bank is low and liable to overflow; the left bank is high and rocky. The bed of the stream is rocky. The station as originally established by J. S. Baker was washed away by the high water in June, 1902, and was reestablished July 30, 1902, by W. W. Schlecht. The original gage was placed on the right bank of the stream. The new gage is located 1,800 feet above the first gage and on the same bank of the stream. The gage was again moved on September 27, 1902, by C. T. Prall, as the second location was directly above a dam. The present gage is located about 900 feet above the former station. The length from the pointer to the bottom of the weight is 4.60 feet. The distance from the zero of the rod to the outside of the pulley is 2.15 feet. Bench mark No. 1 is a point chipped on a large bowlder 32.4 feet south of the gage. Its elevation is 12.52 feet above the zero of the gage. Bench mark No. 2 is the head of a 60-penny wire nail driven in a cottonwood tree 64.4 feet east of the gage. Its elevation is 12.86 feet above the zero of the gage.

Discharge measurements of Swiftcurrent Creek at Henkel's ranch, near St. Mary, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 9	J. S. Baker	1.50	67
Do	do	1.50	68
August 11	W. B. Freeman	2.40	338
August 22	do	2.22	254
September 2	do	1.94	170
October 8	do	2.00	156
October 17	C. T. Prall	1.92	139
October 23	do	1.70	101
October 30	do	1.68	98
July 30	W. B. Freeman	2.50	418
September 22	C. T. Prall	1.85	113
September 29	do	2.05	163

Daily gage height, in feet, of Swiftcurrent Creek at Henkel's ranch near St. Ma Mont.

Day.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	D
1902.									
1	.....	2.00	5.00	3.20	2.50	2.00	1.90	1.60	
2	.....	2.20	4.60	3.50	2.40	2.10	1.90	1.60	
3	.....	2.40	4.00	5.00	2.40	2.10	1.90	1.50	
4	.....	2.20	3.50	7.00	2.40	2.00	1.90	1.50	
5	.....	2.20	3.30	6.30	2.30	2.10	1.80	1.50	
6	.....	2.00	2.90	5.40	2.30	2.50	1.90	1.50	
7	.....	2.00	3.10	5.00	2.20	2.40	1.90	1.50	(
8	1.50	2.00	3.10	4.70	2.10	2.10	1.90	1.50	(
9	1.50	2.60	3.50	3.80	2.10	2.10	1.90	1.50	(
10	1.50	2.80	3.80	3.20	2.40	2.10	1.90	1.50	(
11	1.50	2.90	4.00	3.00	2.30	2.00	1.90	1.50	(
12	1.50	2.90	4.00	3.00	2.30	2.00	1.90	1.50	(
13	1.40	3.10	4.10	2.80	2.30	2.00	1.80	1.50	(
14	1.40	3.10	3.50	2.80	2.30	1.90	1.80	1.50	(
15	1.50	4.00	3.30	2.70	2.20	1.90	1.80	1.50	(
16	1.60	4.10	3.20	2.70	2.20	2.00	1.80	1.50	(
17	1.60	4.40	3.20	2.60	2.20	2.00	1.80	1.50	(
18	1.60	4.40	3.10	2.60	2.20	1.90	1.70	1.50	(
19	1.60	4.00	3.00	2.50	2.30	1.90	1.70	1.50	(
20	1.80	4.40	3.00	2.40	2.30	1.90	1.70	1.50	(
21	2.00	5.70	2.70	2.40	2.30	1.90	1.70	1.50	(
22	2.10	4.90	2.60	2.30	2.20	1.90	1.70	1.50	(
23	2.30	4.70	2.40	2.30	2.20	1.90	1.70	1.50	(
24	2.30	4.30	2.20	2.40	2.20	1.90	1.70	1.50	(
25	2.00	4.10	2.20	2.30	2.20	1.80	1.70	1.40	
26	2.00	3.90	3.50	2.50	2.20	2.00	1.60	1.40	
27	2.00	3.70	3.50	2.40	2.20	2.00	1.60	1.40	
28	2.00	3.80	3.40	2.70	2.20	2.00	1.60	1.40	
29	2.00	4.50	3.40	2.70	2.20	2.00	1.60	1.40	
30	2.00	5.00	3.20	2.50	2.20	2.00	1.70	1.40	
31	.....	5.30	.....	2.50	2.10	.....	1.60	.....	

a River frozen.

Rating table for Swiftcurrent Creek near St. Mary, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Dischar
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-f*
1.0	36	2.8	578	4.6	1,577	6.4	2,57
1.2	45	3.0	689	4.8	1,688	6.6	2,68
1.4	58	3.2	800	5.0	1,799	6.8	2,79
1.6	78	3.4	911	5.2	1,910	7.0	2,90
1.8	108	3.6	1,022	5.4	2,021	7.2	3,0
2.0	156	3.8	1,133	5.6	2,132	7.4	3,1
2.2	245	4.0	1,244	5.8	2,243	7.6	3,2
2.4	356	4.2	1,355	6.0	2,354	7.8	3,3
2.6	467	4.4	1,466	6.2	2,465		

Estimated monthly discharge of Swiftcurrent Creek at Henkel's ranch near St. Mary, Mont.

[Drainage area, 101 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
April *a*			109	6,485	1.08	1.20
May	1,966	156	989	60,811	9.79	11.30
June	1,799	245	880	52,360	8.71	9.71
July	2,909	301	836	51,404	8.28	9.55
August	412	190	276	16,971	2.73	3.15
September	412	108	168	9,996	1.66	1.85
October	128	78	106	6,517	1.05	1.21
November	78	58	66	3,927	.65	.73

a Discharges from 1st to 7th estimated.

ST. MARY RIVER AT DAM SITE NEAR ST. MARY, MONT.

This station was established April 9, 1902, by J. S. Baker. It is located on Henry Henkel's ranch, about 1 mile east of his house, and is 35 miles northwest of Browning, Mont. It is also about 4,500 feet below Lower St. Mary Lake. The gage, which is located about 1,000 feet above the cable from which the measurements are made, is of the usual wire type. It is supported upon a horizontal arm which extends over the river and is fastened to a cottonwood stump. The scale board is graduated to feet and tenths. The length of the wire from the bottom of the weight to the marker is 11.40 feet. The observer is Henry Henkel, who lives about 1 mile west of the gage. The channel is straight both above and below the station and the banks are high. The stream has a moderate velocity and the banks have gentle slopes. The bed of the stream is composed of gravel and bowlders. The initial point for soundings is on the left bank at the middle of the cottonwood tree to which the cable is fastened. Bench mark No. 1 is a spike in the foot of a cottonwood tree 30 feet north of the gage. It is marked B. M. 9.24. Its elevation above the zero of the gage is 9.24 feet. Bench mark No. 2 is a wire spike in the rear post of the gage. It is marked B. M. 6.97 feet. Its elevation above the zero of the gage is 6.97 feet.

Discharge measurements of St. Mary River at dam site near St. Mary, Mont.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Second-feet.*
April 9	J. S. Baker	1.50	94
April 9	do	1.50	97
July 31	W. W. Schlecht	3.55	1,179
August 5	W. B. Freeman	3.20	993
August 12	do	3.05	897
August 23	do	2.73	626
September 2	do	2.47	487
September 22	C. T. Prall	2.00	355
September 29	W. B. Freeman	1.92	267
October 8	do	1.85	232
October 24	A. M. Gilbert	1.73	205
October 30	C. T. Prall	1.65	182

Daily gage height, in feet, of St. Mary River at dam site near St. Mary, Mont.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.									
1		1.70	6.10	4.20	3.50	2.50	1.90	1.70	1.50
2		1.80	6.00	4.40	3.40	2.40	1.90	1.70	1.50
3		2.00	6.00	4.90	3.30	2.40	1.90	1.70	1.50
4		2.00	5.30	6.50	3.30	2.40	1.90	1.70	1.50
5		2.00	5.00	6.60	3.20	2.30	1.80	1.60	1.50
6		2.00	4.60	6.40	3.20	2.30	1.80	1.60	1.50
7		2.00	4.10	6.00	3.10	2.30	1.80	1.60	(a)
8		2.00	4.10	5.80	3.10	2.30	1.80	1.60	
9	1.50	2.20	4.30	5.50	3.10	2.20	1.80	1.60	
10	1.50	2.20	4.30	5.20	3.10	2.20	1.80	1.60	
11	1.50	2.20	4.40	5.00	2.90	2.10	1.80	1.60	
12	1.50	2.20	4.30	5.00	3.00	2.10	1.80	1.60	
13	1.50	2.20	4.30	4.60	3.00	2.10	1.80	1.60	
14	1.50	2.30	4.10	4.60	3.00	2.10	1.80	1.60	
15	1.60	3.00	4.40	4.20	3.00	2.00	1.80	1.60	
16	1.60	3.20	4.30	4.20	3.00	2.10	1.80	1.60	
17	1.60	4.30	4.20	4.20	2.90	2.10	1.80	1.60	
18	1.60	4.30	4.00	4.10	2.90	2.00	1.80	1.60	
19	1.60	4.70	4.00	4.10	2.90	2.00	1.80	1.60	
20	1.50	5.60	4.00	4.00	2.90	2.00	1.80	1.60	
21	1.50	6.00	3.80	4.00	2.90	2.00	1.80	1.60	
22	1.60	6.00	3.60	4.00	2.80	2.00	1.80	1.60	
23	1.70	6.00	3.50	3.90	2.80	2.00	1.80	1.60	
24	1.80	6.30	3.20	4.00	2.70	2.00	1.80	1.60	
25	1.80	6.10	3.20	4.00	2.70	1.90	1.80	1.50	
26	1.60	6.00	3.80	4.10	2.70	1.90	1.70	1.50	1.70
27	1.60	6.00	3.70	3.90	2.70	1.90	1.70	1.50	1.80
28	1.60	5.00	4.00	3.90	2.70	1.90	1.70	1.50	1.70
29	1.60	5.10	4.00	3.80	2.60	1.90	1.70	1.50	1.70
30	1.70	6.00	3.80	3.60	2.60	1.90	1.70	1.50	1.60
31		6.00		3.50	2.60		1.70		1.60

[a] Frozen.

Rating table for St. Mary River at dam site near St. Mary, Mont., for 1902.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.0	27	2.6	600	4.2	1,560	5.8	2,520
1.2	37	2.8	720	4.4	1,680	6.0	2,640
1.4	67	3.0	840	4.6	1,800	6.2	2,760
1.6	140	3.2	960	4.8	1,920	6.4	2,880
1.8	225	3.4	1,080	5.0	2,040	6.6	3,000
2.0	310	3.6	1,200	5.2	2,160	6.8	3,120
2.2	395	3.8	1,320	5.4	2,280		
2.4	480	4.0	1,440	5.6	2,400		

timated monthly discharge of St. Mary River at dam site near St. Mary, Mont.

[Drainage area, 177 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
pril 9–30			136	5,931	0.77	0.63
ay	2,820	310	1,359	83,561	7.68	8.85
ne	2,700	960	1,608	95,682	9.09	10.14
ly	3,000	1,140	1,792	110,186	10.12	11.67
ugust	1,140	600	813	49,989	4.59	5.29
ptember	540	267	357	21,243	2.02	2.25
tober	267	182	222	13,656	1.25	1.44
vember	182	97	137	8,152	.77	.86
cember 1–6 and 26–31			136	3,237	.77	.38

RED RIVER AT EMERSON, MANITOBA.

This station was established by C. M. Hall, July 26, 1900, and is ated at the Emerson railway and traffic bridge one-half mile north the international boundary line at Emerson, Manitoba. It consists a board 1 by 6 inches, painted white, grooved, graduated to feet d tenths, and attached to the east side of the breakwater for the nter stone pier of the bridge. The zero of the gage is 46.5 feet low a steel beam of the bridge directly over the gage, and its elevan is 747.915 feet above sea level. The bed and the banks of the eam consist of clay. Measurements are usually made from a rowat. The observer for 1902 is Robert Rossall, Emerson.

This station now replaces the station at Pembina, N. Dak. readings here were not kept up in 1901 while the gage was mainta at Pembina station, but were resumed when the ice broke up in 1 the Pembina station having been discontinued.

The following measurement was made by C. M. Hall in 1902:

April 26: Gage height, 12.70 feet; discharge, 7,646 second-feet.

Daily gage height, in feet, of Red River at Emerson, Manitoba.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1902.								
1	.....	30.45	14.20	15.35	9.65	5.70	4.40	3.70
2	.....	31.35	15.90	14.75	9.30	5.55	4.40	3.70
3	.....	31.90	18.15	14.20	8.95	5.45	4.35	3.75
4	.....	32.10	20.15	13.60	8.70	5.30	4.30	3.80
5	.....	31.85	21.50	13.20	8.50	5.20	4.30	3.80
6	.....	30.95	22.50	12.95	8.40	5.20	4.40	3.80
7	.....	30.10	23.10	12.80	8.35	5.10	4.40	3.80
8	.....	28.90	23.10	12.80	8.25	5.10	4.40	3.80
9	.....	27.15	23.05	13.05	8.20	5.05	4.30	3.80
10	.....	25.40	22.65	13.55	8.20	5.00	4.30	3.70
11	.....	23.65	21.80	14.05	8.35	5.00	4.30	3.70
12	.....	22.15	21.00	14.50	8.55	4.95	4.35	3.70
13	.....	20.45	20.20	14.65	8.70	4.80	4.40	3.70
14	.....	19.15	19.45	14.75	8.50	4.65	4.30	3.65
15	.....	17.95	18.65	14.70	8.25	4.55	4.25	3.60
16	.....	17.05	17.90	14.60	8.15	4.45	4.15	3.60
17	.....	16.40	17.30	14.40	7.90	4.40	4.10	3.60
18	.....	15.95	16.75	14.15	7.55	4.30	4.10	3.55
19	.....	15.65	16.20	13.90	7.35	4.30	4.00	3.50
20	.....	15.20	15.90	13.65	7.25	4.30	3.90	3.50
21	.....	14.85	15.90	13.45	6.95	4.45	3.80	3.50
22	.....	14.45	16.05	13.05	6.65	4.70	3.75	3.50
23	.....	14.05	16.35	12.80	6.50	4.90	3.70	3.50
24	.....	13.45	16.95	12.55	6.45	4.90	3.70	3.50
25	.....	13.10	17.35	12.10	6.25	4.85	3.70	3.55
26	.....	12.70	17.55	11.75	6.05	4.65	3.60	3.60
27	18.20	12.30	17.60	11.30	5.85	4.45	3.60	3.65
28	21.90	12.00	17.35	10.90	5.70	4.40	3.60	3.75
29	25.10	12.30	17.00	10.45	6.00	4.40	3.60	3.90
30	27.50	13.25	16.40	10.00	5.95	4.40	3.60	4.05
31	29.35	.....	15.95	.....	5.75	4.40	.....	4.55

RED LAKE RIVER AT CROOKSTON, MINN.

This station was established by C. M. Hall, May 19, 1901. I located at the bridge connecting Robert street and St. Paul str which is known as the Sampson addition bridge. The gage consist a weight attached to a woven steel-wire rope which plays over a pu attached to the center of the single-span bridge. Readings are n on a board 1 by 6 inches, painted white, graduated to feet and ten *and attached to the* east railing of the bridge. A similar gage b *nailed to one of* the south piers of the bridge is used for reading

water stages. The zero of the gage is 820.07 feet above sea level and 9.8 feet below the bench mark, which is marked by one 20-penny and three 8-penny nails driven into the east end of the breakwater under the north end of the bridge:

During 1902 the following discharge measurements were made by C. M. Hall:

May 3: Gage height, 9.95 feet; discharge 5.009 second-feet.
May 30: Gage height, 7.85 feet; discharge, 3,154 second-feet.
July 31: Gage height, 5.35 feet; discharge, 1,472 second-feet.

Daily gage height, in feet, of Red Lake River at Crookston, Minn.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
1		8.05	8.15	8.10	6.60	4.75	5.10	5.10	5.18
2		7.75	8.75	7.90	6.70	5.30	5.05	5.25	5.15
3		7.15	9.95	8.30	6.75	5.30	4.95	5.20	5.20
4		7.05	9.65	9.10	6.85	5.40	4.95	5.40	5.18
5		7.35	9.55	9.16	6.93	5.45	4.98	5.07	5.22
6		7.25	9.05	9.10	7.00	5.70	5.00	5.00	5.40
7		6.75	8.90	9.20	6.95	5.60	5.00	4.90	5.45
8		7.25	8.60	9.60	6.93	5.00	4.90	4.95	5.30
9		6.70	8.40	9.80	.....	4.30	4.85	5.01	5.35
10		6.55	8.50	9.70	.....	5.30	4.88	5.04	5.40
11		6.05	8.60	9.60	.....	4.90	4.90	5.02	5.45
12		6.15	8.70	9.60	6.60	5.00	4.95	5.00	5.50
13	[a]7.40	5.85	8.70	9.50	6.50	4.70	4.93	4.98	5.53
14	7.38	5.80	8.80	9.70	6.60	4.50	4.85	4.95	5.50
15	7.42	6.55	8.60	9.30	6.55	4.80	4.83	4.97	5.45
16		6.25	8.50	9.10	6.40	5.30	4.70	4.99	5.50
17	7.63	6.05	8.60	9.00	6.35	4.50	4.70	5.01	5.51
18	7.68	6.25	8.80	9.00	6.30	5.60	4.64	5.04	5.58
19	7.70	5.60	9.10	9.00	6.30	5.60	4.64	5.05	5.60
20	7.85	6.15	9.60	9.00	6.28	5.40	4.65	5.03	5.57
21	7.65	5.15	10.00	8.60	6.25	5.20	4.70	5.03	5.55
22	7.60	5.85	9.80	8.50	6.23	5.10	4.75	5.00	5.53
23	7.95	5.85	9.75	8.50	6.20	4.90	4.74	5.05	5.50
24	8.10	5.85	9.00	8.30	5.95	4.95	4.80	5.10	4.98
25	8.55	5.15	8.98	8.00	5.84	5.00	4.83	5.20	4.96
26	8.81	5.95	8.75	7.40	5.20	5.05	4.86	5.40	4.99
27	9.25	7.75	8.60	7.05	5.15	5.10	4.85	5.34	5.52
28	9.85	7.65	8.60	7.00	4.85	5.10	4.87	5.40	5.54
29	9.60	7.95	8.52	6.90	4.60	5.15	4.90	5.37	5.56
30	9.55	8.00	8.40	6.70	4.92	5.20	4.96	5.35	.....
31	9.00	.....	8.40	.....	4.90	5.10	.....	5.30	.....

[a] Frozen during the winter. Elevation of surface of the ice 7.25 to 7.40 feet on gage. Ice 18 inches thick.

RED RIVER AT GRAND FORKS, N. DAK.

This station was established by C. M. Hall May 26, 1901, and is located at the Northern Pacific Railway bridge crossing the river at Grand Forks, N. Dak. The gage consists of a 1 by 8 inch board, painted white, *graduated to* feet and tenths in black, and attached to *the north end of the breakwater* for the center pier of the bridge.

The zero of the gage was placed 5 feet below the zero of the United States engineers' gage attached to the same breakwater, and is 779.9 feet above sea level according to leveling done by the Corps of Engineers, United States Army. The danger line is at 40 feet. The channel is straight above the station. The bed of the river is composed of mud and fine sand and is changeable; the water is usually heavily laden with sediment from Red Lake River, which enters one-half of a mile above the station. Measurements are made from a rowboat about 150 yards below the gage. The observer is John F. Hayes.

During 1902 the following discharge measurements were made by C. M. Hall:

May 17: Gage height, 15.10 feet; discharge, 6,613 second-feet.[a]
May 30: Gage height, 15.70 feet; discharge, 7,136 second-feet.[a]

Daily gage height, in feet, of Red River at Grand Forks, N. Dak.[b]

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.					1902.				
1	2.30	1.18	3.65	.....	12	1.95	1.35	1.35	.....	23	1.55	1.15	3.80	.....
2	1.95	1.38	3.85	.....	13	1.75	1.22	1.70	.....	24	1.30	1.28	3.50	.....
3	2.25	1.62	3.70	.....	14	1.65	1.15	2.70	.....	25	1.28	1.48	3.45	.....
4	2.30	1.58	3.58	.....	15	1.80	1.08	3.30	.....	26	1.50	1.70	3.20	.....
5	1.95	1.58	3.45	.....	16	1.50	1.62	3.00	.....	27	1.62	1.70	3.50	.....
6	2.15	1.52	3.30	.....	17	1.45	1.50	3.75	.....	28	1.60	2.55	3.20	.....
7	2.05	1.35	3.10	.....	18	1.52	1.38	4.00	.....	29	1.60	2.92	3.00	.....
8	2.25	1.52	3.20	.....	19	1.30	1.30	4.10	.....	30	1.68	3.52	.....	.....
9	2.10	1.53	3.18	.....	20	1.35	1.35	4.20	.....	31	.....	3.50	.....	.....
10	2.05	1.35	2.60	.....	21	1.50	1.22	4.22	.....					
11	2.05	1.55	2.05	.....	22	1.30	1.00	3.85	.....					

SHEYENNE RIVER AT HAGGART, N. DAK.

This station was established March 22, 1902, by Charles M. Hall. It is located near the way station of Haggart, on the Northern Pacific Railroad, 5 miles west of Fargo, N. Dak. The gage is a plain staff graduated to feet and tenths attached to the bridge. It is read daily by James Haggart, jr., who lives about half a mile from the bridge. The channel is straight both above and below the river. The bed of the stream is of clay and slightly shifting.

During 1902 the following discharge measurements were made by C. M. Hall:

April 30: Gage height, 7.90 feet; discharge, 643 second-feet.
May 31: Gage height, 5.50 feet; discharge, 346 second-feet.
September 30: Gage height, 3.70 feet; discharge, 49 second-feet.

[a] Gage height read on Geological Survey gage.
[b] Daily gage heights read on engineers' gage: add 5.00 feet to reduce to U. S. Geol. Survey gage datum.

Daily gage height, in feet, of Sheyenne River at Haggart, N. Dak.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
.....	.....	13.00	8.00	5.50	4.10	3.80	3.80	3.70	3.90
.....	.....	14.80	8.10	5.60	4.20	3.80	3.80	3.90	3.90
.....	.....	15.90	8.10	5.70	4.50	4.00	3.80	3.90	3.90
.....	.....	16.20	8.00	5.50	4.40	4.10	3.80	4.00	3.90
.....	.....	16.50	8.10	5.50	4.30	4.00	3.80	3.90	3.90
.....	.....	17.00	8.00	5.40	4.20	3.90	3.80	3.80	4.00
.....	.....	17.20	7.90	5.40	4.20	3.70	3.80	3.70	4.00
.....	.....	17.40	7.80	5.40	4.10	3.80	3.80	4.00	4.00
.....	.....	18.00	7.60	5.70	4.00	3.80	3.80	4.00	.....
.....	.....	18.00	7.60	6.10	4.30	3.70	3.80	4.10	.....
.....	.....	18.00	7.50	6.50	4.20	3.70	3.80	3.90	.....
.....	.....	17.00	7.50	6.70	4.20	3.60	3.70	3.70	.....
.....	.....	16.40	7.60	6.60	4.00	3.60	3.70	3.70	.....
.....	.....	16.00	7.40	6.20	3.80	3.80	3.70	3.70	.....
.....	.....	15.80	7.20	5.70	3.80	3.80	3.70	3.60	.....
.....	.....	15.50	7.00	5.30	3.70	3.60	3.60	3.60	.....
.....	.....	15.20	7.20	5.20	3.90	3.50	3.60	3.70	.....
.....	.....	15.00	7.00	5.10	4.00	3.40	3.80	3.80	.....
.....	.....	14.80	7.10	5.00	4.00	3.40	3.90	3.90	.....
.....	.....	14.80	7.20	5.00	3.80	3.60	3.80	4.00	.....
.....	.....	14.20	7.20	4.90	3.70	3.70	3.90	3.90	.....
.....	.....	12.30	7.30	4.80	3.80	3.60	3.80	3.80	.....
.....	.....	11.60	7.30	4.70	3.80	3.80	3.70	3.40	.....
.....	.....	10.40	7.40	4.80	3.90	3.80	3.60	3.70	.....
.....	.....	10.20	7.30	4.80	4.00	4.00	3.80	4.20	.....
.....	.....	9.80	7.20	4.60	3.80	4.10	4.00	4.40	.....
.....	.....	9.20	6.90	4.40	4.00	4.00	4.10	4.20	.....
.....	.....	8.60	6.60	4.50	4.50	4.00	4.00	4.00	.....
.....	9.50	8.00	6.30	4.40	4.00	3.80	4.00	4.10	.....
.....	10.20	7.90	6.00	4.20	3.60	3.70	3.80	4.00	.....
.....	12.10	.....	5.60	.....	3.80	3.60	.....	4.00	.....

RED RIVER AT FARGO, N. DAK.

station was established by C. M. Hall May 27, 1901, and is l at the bridge connecting Front street, Fargo, N. Dak., and street, Moorhead, Minn. The gage consists of a 1 by 8 inch painted white, graduated to feet and tenths in black, and ed to the east side of the breakwater for the center pier of the . The zero of the gage is 44.45 feet below the top of the plank of the bridge over the gage and is 860.9 feet above sea level, the ion having been determined by leveling from top of rail of ern Pacific station, Moorhead, Minn. The danger line is at 26.5 Above the station the river curves to the west. The west bank ı and steep; the east bank low and subject to overflow at times h water. Measurements are made from the bridge. The river onsists of soft mud. The observer is H. W. Grasse, United *Weather Bureau, Moorhead*, Minn.

INDEX.

Page.

tts Ferry, California, stream measurements at 159
triz ditch, California, seepage of 181
dor ditch, California, measurements of 158
rican River, California, measurements of 158
rican Valley, California, stream measurements in 157
nas River, Colorado, location of 16
measurements of 35-37
el's ditch, California, measurements below intake of 159
elope Valley, California, stream measurements at upper end of 108
oyo Seco, California, measurements of 163-165
Canyon Creek, Nevada, measurements of 126
ley Creek, Utah, measurements of ... 71-73
ley River, Utah, location of 16
burn, Cal., stream measurements near. 158
sa, Cal., stream measurements at .. 167-171
y Ruth weir, California, stream measurements at 178
rd, Cal., stream measurements at 156
ersfield, Cal., stream measurements near 154-155
ls Ferry, Cal., stream measurements near 157
ls Ferry Bridge, California, Sacramento River at, measurements of 156
ls Ferry Flour Mills, California, stream measurements at 157
ta ditch, California, measurements of. 177
tle Creek, California, measurements in ditch of 157
tle Creek Bridge, California, Sacramento River at, measurements of 157
tlecreek, Idaho, stream measurements at 82-84
Counties Power Company's dam, California, stream measurements below 157
Counties Power Company's flume, California, stream measurements at 157
m ditch, California, natural flow in .. 180
r Creek, California, measurements of. 160

Page.

Bear River, measurements of, at Battlecreek, Idaho 82-84
measurements of, near Collinston, Utah 80-82
miscellaneous measurements of 158
Bennett & Kelley ditch, California, measurements of 162
Bidwell Bar, California, stream measurements at 157
Big Bend, California, stream measurements at 157
Big Bend Tunnel, California, stream measurements at 157
Big Blackfoot River, Idaho, measurements of 216
Big Canyon, California, measurements of. 158
Big Creek, California, measurements of. 160-161
Big Meadows, California, stream measurements at 157
Big Spring Branch of Feather River, California, measurements of 157
Big Trees Creek, California, measurements below mouth of 159
Bitterroot River, Montana, measurements of 201-203
Black Springs Creek, Idaho, measurements of 216
Blackfoot River, Idaho, mouth of, measments above 216
Blacksmith Fork, Utah, measurements of 84-86
Blue Canyon Creek, California, measurements of 160
Blue Creek, Little, Colorado, measurements of 77
Blue Lakes, Idaho, stream measurements at 216
Blue Lakes Creek, Idaho, measurements of 216
Blue Ravine mine, California, stream measurements at 158
Boca, Cal., stream measurements near .. 122
Boise, Idaho, regular gaging station at, stream measurements of 211
stream measurements near 207-210, 216
Boise River, Idaho, measurements of .. 207-211
seepage measurements made on, summary of 212
Boise Valley, Idaho, miscellaneous stream measurements in 211
seepage in 210

Page.
Boise Valley canal, Idaho, measurements of 211
Bonner, Idaho, stream measurements at . 216
Bonton Mills power house, California, measurements in flume at 160
Bowman's reservoir, California, discharge from 157
Bradley's home ranch, Nevada, stream measurements at 106
Bridal Veil Creek, California, measurements of 160
Bridgeport, Cal., stream measurements below 125
Bridgeport Bridge, California, Yuba River (South Fork) at, measurements of 157
Bruneau River, Idaho, measurements of 212-213
Brunnell Hotel, California, West Branch of Feather River at, measurements of 157
Bruns Creek, California, measurements of 126
Bubbs Creek, California, measurements of 161
Buckeye Creek, California, measurements of 125
Buckley, Wash., stream measurements at 217-218
Bulls Head, Arizona, stream measurements at 20-21
Burney, Cal., stream measurements at .. 156
Butt Valley Creek, California, measurements of 157
Cache Creek, California, measurements of 130-132, 157
source and course of 127
Cahoons place, California, Sequoia Natural Park line on, stream measurements at 161
Caldwell bridge, Idaho, Boise River at, measurements of 211
Caldwell Canyon, Idaho, stream measurements in 211
California, southern, stream measurements in drainage basin of .. 163-181
California-Nevada State line, stream measurements at 119-121
Camp Carlton, California, developed water at 180
Camp Seco River, California, measurements of 159
Carbon, Cal., stream measurements at .. 156
Cardston, Canada, stream measurements near 225-226
Carr's ranch, Colorado, stream measurements at 77
Carson River, miscellaneous measurements in basin of 125-126
Carson River (West Fork), California, measurements of 113-115
Carson River, Nevada, measurements of 109-111
Carson River (East Fork), Nevada, measurements of 111-113

Page.
Castle Crags, Cal., stream measurements at 158
Cate ditch, California, measurements of. 157
Catlin & Macey ditches, Idaho, measurements of 211
Cayote Creek, California, measurements of 157
Cebolla Creek, Colorado, measurements of 77
Cedar Lake, Washington, stream measurements at 220
Cedar River, measurements of, near Maple Valley, Washington.. 218-219
measurements of, near Northbend, Wash 220
Cedars, Idaho, stream measurements between Shoshone Falls and..... 216
Cherry Creek, California, measurements of 159
Chillie Bar, California, stream measurements at 158
Chillie Bar Bridge, California, American River (South Fork) at, measurements of 158
Church canal, California, measurements of 161
Cimarron, Colo., stream measurements at 77
Cimarron Creek, Little, Colorado, measurements of 77
Cimarron River, Colorado, measurements of 77
Cippoletti weir, California, headworks of, measurements at 179
City Creek, California, measurements of. 179
Clarke's ranch, Colorado, stream measurements at 77
Clarks Fork, Stanislaus River, California, measurements at and near mouth of 159
Clear Creek, California, measurements of. 162
Kern River below, measurements of. 161
Clear Creek, Nevada, measurements of .. 106
Clear Lake, California, evaporation of.... 132
reservoir site at 127
Clements River, California, measurements of 159
Cliff camp, California, stream measurements near 160
Cohn and Harvey ditch, California, measurements at head of 125
Cohn's meadow, California, Petersons Creek above, measurements of 125
Coleville, Cal., stream measurements near 108
Colfax, Cal., stream measurments near... 156
Colliers, Cal., stream measurements below 159
Collinston, Utah, stream measurements near 80-82
Colorado River, gaging stations in basin of 17
irrigation from 15-16
measurements of, at Bulls Head, Ariz. 20-21
at Yuma, Ariz 17-20
sediment carried by, amount of 15

Page.
·ado River, source and course of 16
·ream measurements in basin of 15-77
·n, Cal., pumping plant at, developed water from 180
·n Terrace Water Co.'s, California, developed water at 180
mbia River, California, stream measurements in drainage basin of 181-216
way & Akin ditches, Idaho, measurements of 211
per City, Cal., Silverthorn Ferry at, measurements of 156
Squaw Creek near, measurements of. 156
tin canal, Idaho, measurements of.... 211
fton canal, California, measurements of 180
fton weir, California, Mill Creek at, measurements of 180
ig, Colo., stream measurements at ... 74-75
·ker Hoffman canal, California, measurements of 160
·kers, California, stream measurements between Hogranch and. 159
·kston, Minn., stream measurements at 234-235
·wn Creek, California, measurements of 160
·monga Creek, California, measurements of 179
is & Hart ditch, Idaho, measurements of 211
is canal, Idaho, measurements of 211
is ranch, California, Kaweah River, North Fork, at lower end of, measurements of 161
·Creek, California, measurements of. 160
h, Nev., stream measurements near. 106
i mine, California, stream measurements below 157
ocrat Springs, California, stream measurements at 162
ls Lake, North Dakota, measurements of 238-239
tream measurements at 238-239
·ond Valley, California, stream measurements at 125
ey Creek, California, measurements of 160
·ion weir, California, stream measurements at 178
n, Colo., stream measurements near. 77
own Creek, California, measurements of 125
·ree, Colo., stream measurements at .. 41-42
·ree River, Colorado, measurements of 41-42
·urce and course of 16
·er Creek, California, measurements of 123
· or Lower Big Spring, California, measurements of 157
e Power ditch, California, headworks of, stream measurements near. 161
·sler Creek, Nevada, *measurements of* 126

Page.
Dry Creek canal, Idaho, measurements of. 211
Dubois, Colo., stream measurements between Spencer, Colo., and ... 77
Duchesne River, Utah, course of 16
measurements of 55-58
Durango, Colo., Animas River at, measurements of 35-37
Florida River near, measurements of. 37-39
Eagle Island, Idaho, stream measurements at 211
East Branch (Feather River), California, measurements of 157
East Mount Moses, Cal., stream measurements at 161
Edison Electric Co., California, cable of, stream measurements at 162
Edwards Bridge, California, Yuba River (South Fork) at, measurements of 157
Eleanor Creek, California, measurements of 159
Electra, Cal., stream measurements at and near 158-159
Electric Light Works waste, Idaho, measurements of 211
Elk River, Colorado, measurements of.... 77
Elko, Nev., Humboldt River near, measurements of 103-105
Humboldt River (South Fork) near, measurements of 101-103
Ellis canal, Idaho, measurements of..... 211
Emerson, Canada, stream measurements at 233-234
Empire, Nev., stream measurements near 109-111
Enterprise, Cal., stream measurements at 157
Enterprise canal, California, measurements of 161
Eureka canal, Idaho, measurements of .. 211
Eureka Lake Co.'s ditch, California, measurements of 157
Evans ditch, California, seepage of 181
Evans Island ditch, California, seepage of 181
Excelsior Mining and Irrigation Co.'s canal, California, measurements of 157
Fairview Creek, Nevada, measurements of 126
Fall River, California, measurements of. 156
Fall River, Idaho, measurements of.... 215-216
Fall River Mills, Cal., stream measurements at 156
Falls Creek, California, measurements of 159
Fargo, N. Dak., stream measurements at 237-238
Farmer's Union canal, Idaho, measurements of 211
Faucherie Lake, California, discharge from 157
Feather River, California, measurements of 133-135, 157
source, drainage basin, and general features of 127-128
Florida River, Colorado, location of..... 16
measurements of 35-39
Folsom, Cal., stream measurements near. 158

Page.

Forbes, R. H., cited on sediment carried by Colorado River 14
Fort Crawford, Colo., stream measurements at 77
Fort Duchesne, Utah, stream measurements at 61-62
Fort Mountain, Cal., stream measurements near 158
Fountain of Life Spring weir, California, stream measurements at 159
Fowler Switch canal, California, measurements of 162
Freemans Bridge, California, Yuba River (Middle Fork), below, measurements of 157
French Lake, California, discharge from. 157
Fruto, Cal., stream measurements near .. 136-137
Gage canal, California, developed water in 180
Gardnerville, Nev., stream measurements near 111-113
Gate View, Colo., stream measurements at 77
Genoa Creek, Nevada, measurements of. 120
Gibbon, Oreg., stream measurements at 183-185
Gila River, Arizona, measurements of 32-35
miscellaneous measurements of 77
source and course of 16
Glenwood Springs, Colo., stream measurements at 48-50
Golconda, Nev., stream measurements near 98-100
Goldwin Mining Company, California, measurements in flume of 159
Goodwin Mill or Penault canal, Idaho, measurements of 211
Grand Forks, N. Dak., stream measurements at 25-26
Grand River, measurements of, at Glenwood Springs, Colo 48-50
measurements of, near Palisades, Colo 46-48
near Piney Creek, Colorado 77
source and course of 16
Grandview, Idaho, stream measurements at 212-213
Granite Creek, California, measurements of 160-161
Grantsdale, Mont., stream measurements near 201-206
Green Creek, California, measurements of 125
Green River, Wyoming, measurements of 75-77
source and course of 16
Greenhorn River, California, mouth of, flow at 158
Greenriver, Wyo., stream measurements at 75-77
Gunnison, Colo., stream measurements near 77
Gunnison, Utah, San Pitch River near, measurements of 94-96
Sevier River near, measurements of. 88-90
Gunnison River, measurements of, at Iola, Colo 44-46

Page.

Gunnison River, measurements of, at Whitewater, Colo 64
Hackett Meadow, California, lower end of, stream measurements at.. 19
Haggart, N. Dak., stream measurements at 28-27
Halleck, Nev., stream measurements near 16
Hamilton, Colo., stream measurements at 77
Hamilton Bridge, California, East Branch of Feather River at, measurements of 157
Hat Creek, California, measurements of. 19
Hawkins Creek, California, measurements of 15
Hayden, Colo., stream measurements at. 77
Heitmans, Nev., spring near, discharge of 19
Henkel's ranch, Montana, Swiftcurrent Creek at, measurements of.. 29-31
Herndon, Cal., stream measurements at. 15-19, 19
Hetch Hetchy Valley, California, lower end of, stream measurements at 19
upper end of, stream measurements at 19
Highlands canal, California, measurements of 19
Hirne Mountain, California, stream measurements at 19
Hog ranch, California, stream measurements between Crockers and. 19
Hooper, Wash., stream measurements near 218-3
Hooper ditch, California, measurements of 1
Horse Creek, California, measurements of 1
Horseshoe Bend, California, stream measurements at 1
Hot Springs, Cal., Thurston ditch on road to, measurements of..... 1
Hoys Bridge, Nevada, stream measurements at 1
Hudson Bay, drainage basin of, stream measurements in 224-
Huff Bar, California, stream measurements at .....
Humboldt River, measurements of, at Palisade, Nev .....
measurements of, below Pitt dam, Nevada .....
near Elko, Nev 103-
near Golconda, Nev 98-
near Oreana, Nev 96
miscellaneous measurements in basin of .....
Humboldt River (North Fork), Nevada, measurements of .....
Humboldt River (South Fork), Nevada, measurements of 101-
Hunter ranch, California, stream measurements below .....
Hydraulic Mining Company's canal, California, measurements of .....
Hydrographers, resident, in various States and Territories 1
Hyrum, Utah, stream measurements at .. 5

Page.

Ramona Water Company, California, head works of, stream measurements above 179
Ideal Valley, California, stream measurements at 160
Ignacio, Colo., stream measurements at.. 39-40
Illilouette Creek, California, measurements of 160
Imperial canal, Arizona, location and purpose of 15-16
measurements of 77
Independence Creek, California, measurements of 121-122
Independence Lake, California, measurements below 121-122
Index, Wash., stream measurements near 222-223
Indian Agency, California, Tule River below, measurements of 161
Indian Creek, California, measurements of 125
Indian Reservation, California, stream measurements between Nelson and 161
Indian Valley, California, stream measurements in 157
International boundary, stream measurements at 77
Interior, stream measurements in drainage basin of 78-126
Iola, Colo., stream measurements at..... 44-46
Iowa Hill road bridge, California, American River (North Fork) above, measurements of 158
Irish-American ditch, Nevada, measurements of 124
Iron Canyon, California, stream measurements at 137-141
Irrigation projects in western half of United States, location of, map showing 12
Isabella, Cal., stream measurements between Kernville and 162
Jackass Creek, California, measurements of 160
Jacks Valley Creek, Nevada, measurements of 126
Jacksonville, Cal., stream measurements at 160
Jacobs canal, Idaho, measurements of.. .. 211
James Canyon Creek, Nevada, measurements of 126
Jellys Ferry, California, stream measurements at 137-141
Julian's ranch, California, stream measurements at 135-137
Junction Valley, Utah, seepage in..... 94
water diverted for irrigation in..... 92, 94
water entering 90, 94
water leaving 93-94
Kaweah River, California, miscellaneous measurements of 161
Kern River, California, irrigation from. 129
measurements of 154-155, 162
Kern River, Little, California, *measurements of* 162

Page.

Kern River Power Company, Cal., powerhouse of, Kern River at, measurements of 162
Kernville, Cal., stream measurements between Isabella and 162
King City, Cal., stream measurements near 166-167
King River, measurements of, at Kingsburg, Cal. 149
measurements of, near Sanger, Cal. 150-151
miscellaneous measurements of 160
source and regimen of 128-129
Kings Canyon Creek, Nevada, measurements of 126
Kingsburg, Cal., stream measurements at 149, 161
Kingsburg canal, California, measurements of 161
Kingsbury Creek, Nevada, measurements of 126
Kiona, Wash., stream measurements at. 186-188
Knights Ferry, Cal., stream measurements below 159
Lagrange, Cal., stream measurements at 142-146, 160
Lagrange dam, California, stream measurements above 160
Lagrange ditch, California, measurements of 160
Lake Creek, Utah, measurements of..... 58-61
Lake Eleanor trail crossing, California, stream measurements below. 159
Lake Fork, Colorado, measurements of.. 77
Lakeport, Cal., evaporation at 132
Lamburger & Ryan ditch, Idaho, measurements of 211
Lancha Plana dam, California, stream measurements below 159
Laurel Creek, California, stream measurements between Ockenden and 160
Lathos Creek, Colorado, measurements of 77
Leland, Utah, stream measurements near 52-55
Lemon Cove, Cal., stream measurements between Three Rivers and... 161
Lippincott, J. B., work done by 16
Livingstone, Ariz., Salt River near, measurements of 25-29
Tonto Creek near, measurements of.. 29-32
Little Grass Valley, California, stream measurements in 157
Logan, Utah, stream measurements at.. 86-87
Logan River, Utah, measurements of.... 86-87
Long Valley Creek, measurements of, at Diamond Valley, California 125
measurements of, at Long Valley reservoir site, Nevada..... 125
above Springmeyer's ranch, Nevada 125
Long Valley reservoir site, Nevada, stream measurements at dam at 125
Los Pinos River, Colorado, location of 36
measurements of 39-40

Page.

Love Creek, California, measurements below junction of Moran Creek and 159
Lower lake, California, stream measurements at 130-132
Lytle Creek, California, measurements of 179
McCarty canal, Idaho, measurements of.. 211
McCloud River, California, measurements of 156
McCoy's ranch, Colorado, stream measurements near 77
McDowell, Ariz., Salt River at, measurements of 23-25
Verde River near, measurements of... 25-23
McFarlands bridge, California, Tulo River at, measurements of 161
Malo, Mont., stream measurements at. 225-228
Mancos, Colo., stream measurements at... 77
Mancos River, Colorado, measurements of 77
Maplevalley, Wash., stream measurements near 218-219
Marble Fork, Kaweah River, California, measurements of 161
Marys River, Nevada, measurements of. 106
Marysvale Valley, Utah, water diverted for irrigation in 92, 94
water entering 93, 94
water leaving 93-94
seepage in 94
Marysville, Idaho, stream measurements near 215-216
Mason Slough, Nevada, measurements of. 125
Mason Valley, Nevada, stream measurements in 125
Mason's ranch, Nevada, stream measurements at 101-103
Matilija, Cal., Ventura River at, measurements of 177
Meadow View Hotel, California, stream measurements near 157
Meeker, Colo., stream measurements at... 50-52
Meeks & Daley ditch, California, natural flow in 181
Mendota, Cal., stream measurements at. 160
Merced Falls, Cal., stream measurements above 147-148
stream measurements near 160
Merced River, California, drainage area of 128
measurements of 147-148, 160
Meritt ditch, Nevada, measurements of... 125
Middle Fork, Kaweah River, California, measurements above 161
Middle Fork, San Joaquin River, California, measurements of 160
Middleton, Idaho, waste east of, measurements of 211
Middleton Canal Company canal, Idaho, measurements of 211
Middleton Mill Slough, Idaho, measurements of 211
Middleton Water Company canal, Idaho, measurements of 211
Mill Creek, California, measurements of . 159, 179

Page.

Miller & Lux canal, California, measurements of 160
Miller Bridge, California, San Joaquin River above, measurements of 160
Milton (now Angels) ditch, California, measurements of 159
Minidoka, Idaho, stream measurements near 213-214
Mink, Cal., stream measurements near ... 158
Missoula, Mont., stream measurements at 199-201
Missoula River, Montana, measurements of 199-201
Mohave River, California, measurements of 175-177
Mokelumne ditch, California, measurements of 158
Mokelumne River, California, miscellaneous measurements of 158-159
Mono, Cal., stream measurements between Pine Ridge and 160
Mono Creek, California, measurements of 160
Montgomery Ferry, Idaho, stream measurements at 213-214
Moran Creek, California, measurements below junction of Love Creek and 159
Motts Creek, Nevada, measurements of... 126
Mount Whitney Power Company's flume, California, measurements of... 161
Muldoon ditch, Nevada, measurements of 126
Murphy ditch, lower, California, measurements of 162
Murphy ditch, upper, California, measurements of 162
Mystic, Cal., stream measurements at... 119-121
Naches River, Washington, measurements of 191-194
Natoma ditch, California, measurements of 158
Negro Hill canal, California, measurements of 158
Nelson Creek, California, measurements above mouth of 157
Nelsons, Cal., stream measurements between Indian Reservation and. 161
Nevada-California State line, stream measurements at 119-121
New York canal, Idaho, measurements of 211, 216
Newell, F. H., letter of transmittal by... 9
Nordyke, Nev., stream measurements at. 125
North Bloomfield ditch, California, measurements of 157
North Columbia, Cal., stream measurements at 157
North Fork canal (American River), California, measurements of 158
North Yakima, Wash., Naches River near, measurements of 191-194
Tieton River near, measurements of 194-196
Northbend, Wash., stream measurements near 220

Page
:, Cal., stream measurements at.. 159
en, Cal., stream measurements between Laurel Creek and..... 160
ission bridge, California, San Gabriel River at, measurements of 177
aho, stream measurements at and near..... 215-216
, Nev., stream measurements near..... 96-98
e, Cal., stream measurements at. 133-135
n, Cal., stream measurements near..... 121-122
Cal., stream measurements near. 158
o canal, California, measurements of..... 157
e, Nev., Humboldt River at, measurements of..... 100
e Creek at, measurements of..... 101
es, Colo., stream measurements near..... 46-48
River, Washington, measurements of 203-205
tch Valley, Utah, seepage in..... 94
er diverted for irrigation in..... 92, 94
er entering 90, 94
er leaving 93, 94
Creek, Nevada, measurements of 126
s Ferry, California, stream measurements at..... 159
canal, Idaho, measurements of.. 211
Bridge, California, stream measurements at 156
s, Nev., stream measurements at. 126
s ditch, Nevada, measurements of. 126
canal or Goodwin Mill, Idaho, measurements of..... 211
ns Creek, California, measurements of 125
ranch, California, Arroyo Seco at, measurements of 163-165
canal, Idaho, measurements of... 211
eek, Colorado, measurements of.. 77
eek, Nevada, measurements of... 101
idge, Cal., stream measurements between Mono and 160
reek, Colorado, Grand River near, measurements of 77
canal, California, measurements of..... 161
canal, Idaho, measurements of.. 211
n, Nevada, stream measurements below 124
iver, California, miscellaneous measurements of..... 156
ille, Cal., stream measurements near..... 158
ille ditch, California, measurements of 158
t Valley, Cal., stream measurements at 157
Creek, California, measurements of..... 179
y, Cal., stream measurements at. 160
ville, Cal., stream measurements and near 151-153, 161
lle, Cal., stream measurements at. 157

Page.
Price road bridge, Utah, Duchesne River at, measurements of 55-58
Prosser Creek, California, measurements of..... 122
Provo, Utah, stream measurements near. 88
Provo River, Utah, measurements of 88
Puget Sound, drainage basin of, stream measurements in 216-224
Quincy, Cal., stream measurements near. 157
Rancheria Creek, California, measurements of 159
Ranchero & Bloomington ditch, California, developed water in..... 180
Red Bluff, Cal., stream measurements near..... 137-141
Red Lake River, Minnesota, measurements of 234-235
Red Mountain, California, stream measurements at 150-151, 161
Red River, measurements of, at Emerson, Canada..... 233-234
measurements of, at Fargo, N. Dak. 237-238
at Grand Forks, N. Dak 235-236
Redlands canal, California, measurements of 179
Redlands tunnel, California, stream measurements at 179
Resident hydrographers in various States and Territories..... 14-15
Rialto canal, California, measurements above intake of..... 179
measurements at, weir headworks of. 179
Ridenbaugh canal, Idaho, measurements of..... 211
Rincon, Cal., seepage at..... 181
River stations and principal irrigation projects in western half of United States, location of, map showing..... 12
River stations in eastern half of United States, location of, map showing 13
Riverside, West, pumping plant, Cal., developed water from..... 180
Riverside canal, California, seepage of... 181
Riverside canal, Idaho, measurements of. 211
Riverside Narrows, California, seepage at and above..... 181
Riverside Water Company's, California, flume of, seepage in..... 181
mill flume of, natural flow in..... 180
mill pump of, developed water from. 180
upper canal of, natural flow and developed water in 180
Riverton, Cal., stone bridge at, stream measurements above..... 158
Roaring River, California, measurements of 161
Robe, Wash., stream measurements near..... 223-224
Robinson Creek, California, measurements of 125
Robinsons Box, Nevada, stream measurements at 126
Robinsons Ferry, California, stream measurements at 159
Rock Creek, Colorado, measurements of. 77

Page.
Rodenbah's ranch, Nevada, stream measurements at 111-113
Rodgers ditch, Nevada, measurements of 124
Rogers pumping plant, California, developed water from 180
Ross ranch, Nevada, stream measurements at 107-108
Rossi logging canal, Idaho, measurements of 211
Rossi waste, Idaho, measurements of 211
Rubicon River, California, measurements of 158
Rubidoux canal, California, seepage of .. 181
Sacramento, Cal., stream measurements at 15
Sacramento River, California, measurements of 137-141, 156-157
source and course of 127
St. Mary, Mont., St. Mary River near, measurements of 231-233
Swiftcurrent Creek near, measurements of 229-231
St. Mary River, measurements of, at Main, Mont 226-228
measurements of, near Cardston, Canada 225-226
near St. Mary, Mont 231-233
Salmon Creek, California, measurements of 162
Salmon Falls, Cal., dam at, stream measurements below 158
Salt River, Arizona, measurements of, at McDowell, Ariz 23-25
measurements of, near Livingstone, Ariz 25-29
source and course of 16
San Antonio Creek, California, measurements of 159, 178-179
San Antonio tunnel, California, stream measurements at 179
San Bernardino Valley, California, developed water in, compared with natural flow of Santa Ana River 180
seepage in 181
San Carlos, Ariz., stream measurements at 32-35
San Francisco Bay, stream measurements in drainage basin of 127-162
San Gabriel canals, California, measurements of 167-171
San Gabriel Electric Company's power house, California, concrete weir basin at, measurements at 178
San Gabriel River, California, miscellaneous measurements of 177
San Joaquin power house, California, stream measurements near ... 160
San Joaquin River, California, measurements of 155-156, 160, 167-171
valley of, features in 127
San Lorenzo Creek, California, measurements of 166-167
San Juan River, source and course of 16
San Pitch River, Utah, measurements of 94-96

Page.
Sand box weir, California, Redlands canal at, measurements of 179
Sanger, Cal., stream measurements near 150-151
Santa Ana canal, California, measurements of 171-175
Santa Ana River, California, measurements of 171-175, 178-180
natural flow, compared with developed water in San Bernardino Valley 180
seepage along 181
Santa Ana River flume, California, Riverside pumping plant No. 1, developed water from 180
Riverside pumping plant No. 2, developed water from 180
Sebree canal, Idaho, measurements of ... 211
Sebree River, Idaho, measurements of ... 211
Sediment carried by Colorado River, amount of 15
Seibenberg Slough, Idaho, measurements of 211
Sequoia National Park line, California, stream measurements above ... 161
Settlers canal, Idaho, measurements of .. 211
Seventy-six canal, California, measurements of 161
Sevier River, Utah, measurements of 88-90
seepage measurements in basin of 90-94
Sheep Creek, California, measurements of 161
Sheridan Creek, Nevada, measurements of 123
Sheyenne River, North Dakota, measurements of 236-237
Shoshone Falls, Idaho, stream measurements between the Cedars and 216
stream measurements between Twin Falls and 216
Silver Creek, California, measurements of. 158
Silverthorn Ferry, California, measurements of 156
Simpsons Meadows, California, stream measurements below trail to .. 160
Skykomish River (South Fork), Washington, measurements of 222-223
Slanson well, California, discharge of 17
Slover Mountain, California, seepage below 181
Smartsville, Cal., stream measurements at 157
Smiths Valley, Nevada, stream measurements in lower end of 125
Snake River, Colorado, measurements of . 7
Snake River, Idaho, measurements of . 213-215
Snelling, Cal., stream measurements below 160
Snoqualmie Falls, Washington, stream measurements above 220-222
Snoqualmie River, Washington, measurements of 220-222
Soda Creek, Upper, California, stream measurements at 156
Soldiers Camp, California, stream measurements between Tar Gap and 168

Page.
s' Home, Idaho, stream measurements above 211
d, Cal., stream measurements near 163-165
s Creek, California, measurements of 125
y ditch, California, measurements of 159
Fork (American River), California, measurements above mouth of 158
Fork bridge, California, Mokelumne ditch below, measurements of 158
Riverside ditch, Nevada, measurements of 124
Yuba Water Company, California, dam of, stream measurements below 158
w power canal of, measurements of 158
west ditch, Nevada, measurements of 124
sh Creek, California, measurements of 157
er, Colo., stream measurements between Dubois, Colo., and 77
ne, Wash., stream measurements at 196-198
ne River, Washington, measurements of 196-198
g Creek, Colorado, measurements of 77
g Hill weir, California, stream measurements at 178
gmeyer's ranch, Nevada, stream measurements above 125
v Creek, California, measurements of 156
v Creek bridge, California, stream measurements at 156
rd & Neil ditch, California, measurements of 162
rd ditch, lower, California, measurements of 162
ard dam, California, stream measurements above 125
ard ditch, California, flume No. 59 of, measurements of 158
ard Electric Company's power house, California, stream measurements above 159
ifer ditch, California, measurements of 177
laus River, California, miscellaneous measurements of 159
laus Water Company's canal, California, measurements below intake of 159
asurements in flume No. 3 of 159
daho, stream measurements below. 211
ridge, Idaho, Boise River at, measurements of 211
boat Springs, Colo., stream measurements at 77
uamish River, Washington, measurements of 223-224
Creek, California, drainage area and course of 128
asurements of 135-137
Strahorn canal, Idaho, measurements of. 211
Stream measurements, publications containing (list) 12-13
Strosnider's ranch, Nevada, stream measurements at 125
Sumner ditch, California, measurements of 162
Susan River, California, measurements of 123-124
Susanville, Cal., stream measurements near 123-124
Swamp ditch, California, natural flow in. 180
Swanger Creek, California, measurements of 125
Sweetwater Creek, Nevada, measurements of 125
Swiftcurrent Creek, Montana, measurements of 229-231
Tahoe, Cal., stream measurements at .. 115-117
Tar Gap, Cal., stream measurements between Soldiers Camp and .. 161
Taylor River, Colorado, measurements of. 77
Tenaya River, California, measurements of 160
Tenmile Creek, Idaho, waste in, measurements of 211
Threerivers, Cal., stream measurements above 161
stream measurements between Lemon Cove and 161
Thorn ditch, Nevada, measurements of .. 126
Thurston ditch, California, measurements of 162
Tieton River, Washington, measurements of 194-196
Till-Till Creek, California, measurements of 159
Tobias Creek, California, measurements of Kern River between Salmon Creek and 162
Tonto Creek, Arizona, measurements of. 29-32
Trimmer Springs, Cal., stream measurements at 161
Truckee, Cal., stream measurements near 123
Truckee River, measurements of, at Nevada-California State line . 119-121
measurements of, at Tahoe, Cal.... 115-117
at Vista, Nev 117-119
near Mystic, Cal. 119-121
Trull, Colo., stream measurements at 77
Tule River, California, drainage area of and irrigation from 129
measurements of 151, 153, 161-162
Tunnel ditch, Nevada, measurements of 125
Tuolumne Electric Power Company's canal, California, measurements near intake of 159
Tuolumne Meadows, Cal., lower end of, stream measurements at 159
Tuolumne River, California, measurements of 142-146, 159-160
source and drainage basin of 128
Turlock canal, California, measurements of 144-146, 160
Twin Creek, East, California, measurements of 179

Page.
Twin Creek, West, California, measurements of 179
Twin Falls, Idaho, stream measurements between Shoshone Falls and.. 216
Twin Lakes, Cal., stream measurements below 125
Uinta, Utah, stream measurements near. 87
Uinta River, measurements of, at Fort Duchesne, Utah 61-65
measurements of, near Leland, Utah. 52-55
near Whiterocks, Utah 65-68
Umatilla River, Oregon, measurements of 183-185
Uncompahgre River, Colorado, measurements of 77
Union canal, Idaho, measurements of 211
Union canal, Nevada, measurements of .. 124
Union Gap, Wash., stream measurements at 188-190
Upper Bairds station, Cal., stream measurements at 156
Vanardsdale Clubhouse, California, stream measurements at 156
Ventura River, California, miscellaneous measurements of 177
Verde River, Arizona, measurements of . 21-23
Vernal, Utah, stream measurements near 71-73
Victorville, Cal., stream measurements at 175-177
Vista, Nev., stream measurements at.. 117-119
Wabuska, Nev., stream measurements near 106-107
Wagon bridge, Utah, Lake Creek (near mouth) at, measurements of.. 58-61
Walker River, measurements of, at Nordyke, Nev 125
measurements of, near Wabuska, Nev 106-107
miscellaneous measurements in basin of 125
Walker River (East Fork), Nevada, measurements of 107-108
Walker River (West Fork), California, measurements of 108
Walker River, East, California, miscellaneous measurements of 125
Walker River, East, Nevada, miscellaneous measurements of 125
Walker River, West, California, miscellaneous measurements of 125
Walsh ditch, measurements of 126
Ward & Warren ditch, California, natural flow and developed water in 180
Wards Ferry, Cal., stream measurements at 159
Warmsprings, Cal., stream measurements at 171-175
Water company's ditch, Nevada, measurements of 126
Wawona, Cal., stream measurements at. 160
Weber River, Utah, measurements of.... 87
Webster's ranch, Nevada, stream measurements at 125

Page.
Weiser, Idaho, stream measurements near 216-217
Weiser River, Idaho, measurements of. 216-217
Weldon crossroads, California, stream measurements above 162
West Branch (Feather River), California, measurements of 157
West Point, Cal., stream measurements near 158
West Riverside Bridge, California, seepage at 161
Wheaton's, Tom, ranch, California, stream measurements at 161
White River, measurements of, at Buckley, Wash 217-218
measurements of, at Meeker, Colo..... 50-52
Whiterocks, Utah, Uinta River near, measurements of 65-68
Whiterocks River near, measurements of 68-71
Whiterocks River, Utah, measurements of 68-71
Whitewater, Colo., stream measurements at 42-44
Williams Fork, Colorado, measurements of 77
Willow Creek, Idaho, waste from, measurements of 211
Wilsons Ford, Nevada, stream measurements at 125
Wilsons mill, Idaho, Fall River at, measurements of 215-216
Woodbridge, Cal., stream measurements at 159
Woodbridge canal, California, measurements of 159
Woodfords, Cal., stream measurements at 113-115
Woodlands, Cal., stream measurements near 157
Woods Creek, California, measurements of 160
Yakima River, measurements of, at Kiona, Wash 186-188
measurements of, at Union Gap, Wash 188-190
Yampa River, Colorado, character, source, and course of 16
measurements of, at Craig, Colo 74-75
at Hayden, Colo 77
at Steamboat Springs, Colo 77
Yankee Hill Bridge, California, West Branch of Feather River above, measurements of 157
Yerington, Nev., stream measurements near 107-108
Yolo Bridge, California, Cache Creek at, measurements of 157
Yosemite Valley, California, stream measurements of 160
Yuba River, California, measurements of. 157
Yuma, Ariz., pumping plants deriving water from Colorado River at. 15
stream measurements at 17-20

Water-Supply and Irrigation Paper No. 86 Series J, Water Storage, 8

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

STORAGE RESERVOIRS

ON

STONY CREEK, CALIFORNIA

BY

BURT COLE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

CONTENTS.

	Page.
transmittal	7
ion by J. B. Lippincott	9
and organization of work	9
r supply of Sacramento Valley	10
conditions	12
n	13
rigation district	14
eorganization of Central irrigation district	19
ay	20
Stony Creek Forest Reserve	20
ion and climate	23
	32
	35
ossibilities	36
stone Creek	36
Creek	36
Fork of Stony Creek	36
e Creek	37
Stony Creek; East Park reservoir site	47
ite; reservoir site	56
	59
ns	60

ILLUSTRATIONS.

		Page.
ATE I.	Orange tree, Willows, Cal	10
II.	*A*, Sacramento Valley wheat farm near Willows; *B*, Typical ranch house of wheat farm near Willows	12
III.	Sacramento River opposite Willows	14
IV.	*A*, Central Irrigation District canal opposite Jacinto; *B*, Central Irrigation District canal near St. Johns	16
V.	*A*, Black Butte; *B*, Stony Creek gaging station	22
VI.	Briscoe Creek dam site	38
VII.	Briscoe Creek reservoir site	40
VIII.	Briscoe Creek dam site abutment	42
IX.	*A*, East Park dam site on Little Stony Creek; *B*, West half of East Park reservoir site	46
X.	East Park reservoir site	48
XI.	*A*, Conglomerate at East Park; *B*, Mill Site dam site on Stony Creek	50
XII.	Mill Site reservoir site	52
XIII.	Plan of concrete dam, East Park dam site	54
XIV.	Mill Site dam site, rock-filled dam	56
XV.	Plan of Mill Site dam	56
XVI.	Alfalfa field, Brown's ranch, Stony Creek Valley	58
1.	Mean monthly precipitation at Woodlands, Fouts Springs, and Red Bluff	27
2.	Briscoe dam site, Stony Creek	37
3.	Capacity curve, Briscoe reservoir	38
4.	Plan of concrete dam, Briscoe reservoir	38
5.	Section of concrete dam, Briscoe reservoir	39
6.	Plan of spillway, Briscoe reservoir	40
7.	Section of spillway, Briscoe reservoir	40
8.	Plan of concrete overflow dam, Briscoe reservoir	42
9.	Elevation of concrete overflow dam, Briscoe reservoir	43
10.	Cross section of concrete overflow dam, Briscoe reservoir	43
11.	Plan of subsidiary earth dam, Briscoe reservoir	44
12.	Cross section of subsidiary earth dam, Briscoe reservoir	44
13.	Plan of rock-filled dam, Briscoe dam site	45
14.	Section of rock-filled dam, Briscoe dam site	45
15.	Plan of spillway, Briscoe dam site	46
16.	Section of spillway, Briscoe dam site	46
17.	Capacity curve, East Park reservoir	48
18.	East Park dam site	49
19.	Maximum cross section of concrete dam, East Park dam site	50
20.	Profile of dam site, East Park dam site	50
21.	Outlet tunnel, East Park dam site	51
22.	Profile of spillway, concrete dam, East Park dam site	51

Page.
FIG. 23. Cross section of spillway, concrete dam, East Park dam site 51
24. Plan of rock-filled dam, East Park dam site 52
25. Maximum cross section, rock-filled dam, East Park dam site 52
26. Downstream elevation, rock-filled dam, East Park dam site 53
27. Upstream elevation, rock-filled dam, East Park dam site 53
28. Detail of plank face, rock-filled dam, East Park dam site 53
29. Plan showing relative position of waste way, rock-filled dam, East Park dam site 54
30. Cross section of waste way, rock-filled dam, East Park dam site 54
31. Plan of waste way, rock-filled dam, East Park dam site 54
32. Profile of waste way, rock-filled dam, East Park dam site 55
33. Outlet of tunnel, rock-filled dam, East Park dam site 55
34. Plan of valves, rock-filled dam, East Park dam site 56
35. Tunnel cross section, rock-filled dam, East Park dam site 56
36. Section of Mill Site dam 57
37. Section of spillway, Mill Site dam 58
38. Capacity curve, Mill Site reservoir 59

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., February 21, 1903.

R: I have the honor to transmit herewith manuscript of a paper Mr. Burt Cole, entitled "Storage Reservoirs of Stony Creek, Cali- ia," and request that it be published in the series of Water-Supply Irrigation Papers. The paper treats of the possibilities of reclaim- by irrigation large areas of land in the valley of Stony Creek, a utary of the Sacramento River, and on the west side of the ramento Valley, which have been cultivated by dry farming, but on ch irrigation may apparently be introduced with much advantage.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Ion. CHARLES D. WALCOTT,
Director United States Geological Survey.

STORAGE RESERVOIRS ON STONY CREEK, CALIFORNIA.

By BURT COLE.

INTRODUCTION.

By J. B. LIPPINCOTT.

SCOPE AND ORGANIZATION OF WORK.

Recognizing the fact that the general and permanent prosperity of ılifornia is largely dependent upon successful agricultural develop-ent, and furthermore that in the great central valleys of the State rming without irrigation has caused, during the last decade, a ·crease in land values, as well as in population, it was deemed desir-ıle to investigate the possibilities of irrigation development in certain pical interior districts of the State. In the above connection the ılifornia Water and Forest Association requested the United States eological Survey to make a study of Glenn County to ascertain if ıitable reservoir sites could be found on Stony Creek, so that the aters of that stream could be put upon the higher and warmer mar-nal lands on the western side of the Sacramento Valley. Willows the county seat of Glenn County, and the chamber of commerce of ıis town, through the Water and Forest Association, contributed ;50 additional toward defraying the expenses of this study. The ıld work has been entirely under the direction of the Hydrographic ranch of the Geological Survey, and the greater part of the expense ıs been borne by that Survey.

The greater portion of this investigation has been devoted to the ainage basin of Stony Creek. However, by far the greatest natural ıter supply for Glenn and neighboring counties is the Sacramento ver, which is the largest navigable river of the State, and forms ; eastern boundary of Glenn County. The difficulty of using this er lies in the expense and magnitude of works necessary for its ersion, especially if its waters are to be put upon the higher valley ıds. The interference with navigation by the diversion of water m the river during its low stage is a serious question. It is con-ered pertinent, however, to briefly refer to the Sacramento River l its possible *utilization*.

WATER SUPPLY OF SACRAMENTO VALLEY.

The seasonal rotation in the Sacramento Valley much resembles that in the southern valleys of the State situated between the Sierra Nevada and the Coast Range. There is more rain in the Sacramento Valley, but it falls in the same months. There is a distinct dry summer extending from April until October. In midsummer the temperature is at times as high as 114°, and the relative humidity is low, ranging from 10 to 20 per cent. In the other half of the year the rainfall ranges from 25.56 inches at Red Bluff, at the head of the Sacramento Valley, to 18.19 inches at Woodland, in Yolo County. The minimum temperature recorded by the United States Weather Bureau at Red Bluff since 1878 is 18°. These temperatures permit the growth of all of the products of the State. A compilation of physical statistics for Red Bluff by Mr. Maurice Connell, observer for the United States Weather Bureau, is given in this report. They show in detail the conditions here referred to.

Surrounding Sacramento Valley on the north, east, and west are high ranges of mountains culminating in Mount Shasta, at the northern apex of the valley, with an elevation of 14,380 feet. Upon the crest of these ranges, the Sierra Nevada on the east and the Coast Range on the west, the precipitation is much greater and occurs usually in the form of snow, which remains at the higher altitudes until melted by the summer sun. As the mountains are higher to the north and east of the valley than to the west, the precipitation is greater there, the temperature is lower, and the snow remains unmelted until later in the summer. The stream conditions resulting from these physical conditions may readily be inferred. From the higher sierras the creeks begin to rise with the fall rains, and the precipitation in the foothills causes them to maintain their flow throughout the winter. Under normal conditions, however, they reach stages of maximum discharge in the spring and early summer, when the snows at the higher levels are melting. They reach their lowest stages in September. On the western side of the valley the streams issuing from the Coast Range, to which class Stony Creek belongs, flow from lower and warmer levels. Consequently the precipitation is more often in the form of rain and the snow is more quickly melted. The resulting stream flow, therefore, is more irregular and the maximum periods of flow are in winter and early spring. These Coast Range streams are reduced to very low discharge throughout the summer months, and their proper utilization is largely dependent upon the construction of reservoirs for the conservation of the winter water. There is therefore a cool, wet winter in the valley, followed by a hot, dry summer. The Sacramento and its eastern tributaries are strong streams during the winter, spring, and early summer, and have relatively low discharges in September and October, while the western tributaries are normally high in winter and early spring and almost dry in the summer. These conditions not only demand the irrigation

ORANGE TREE, WILLOWS, CAL.

lley, but furnish the opportunity therefor. Tables of dis- the Sacramento River and of Stony Creek are made a part port and illustrate the above statement.

gher marginal valley lands are better drained and warmer low lands. They are not so well adapted to the growth of the soil is not so strong, but it is believed that with irrigation ld be among the finest fruit lands of the State, capable of g the olive, vine, and orange.

lley of the Po, in northern Italy, is the greatest artificially listrict of Europe. In this region irrigation has been prac- inuously for over one thousand years. The values of water igated lands have continually increased, and to-day it stands mple of most intensive cultivation, supporting 391 persons e mile in the irrigated district.

llowing interesting comparison may be made between the onditions of Milan, in the heart of this district, and those pper Sacramento Valley. R. Baird Smith, lieutenant of , British service, in a work entitled "Italian Irrigation," is rity for the statements on Italian irrigation. The record of nd temperature for Milan was obtained from the United eather Bureau. It probably extends back into the eighteenth For monthly maximum and minimum records at the head cramento Valley, see the Red Bluff record given later in this

n of climatic conditions in Sacramento Valley and in northern Italy.

nth.	Rainfall.		Temperature.			
	Woodlands, Cal.	Milan, Lombardy.	Woodlands, Cal., Mean.	Milan, Lombardy.		
				Max.	Min.	Mean.
	Inches.	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*
.....	3.67	2.28	42.6	55	7	33
.....	2.56	2.34	45.5	71	19	38
.....	2.72	2.60	48.9	74	21	46
.....	1.75	3.59	55.5	82	27	54
.....	.85	4.06	62.1	91	39	62
.....	.12	3.30	70.1	97	48	70
.....	.00	2.92	77.9	99	54	74
.....	.02	3.66	76.1	95	53	72
.....	.25	3.82	68.6	91	46	65
.....	.92	4.93	60.4	78	33	55
.....	2.01	4.22	50.4	63	23	43
.....	3.42	2.87	43.5	61	10	36
al	18.25	40.59	58.5	99	7	54

The minimum temperature at Woodlands is not available. The lowest temperature recorded at Red Bluff by the Weather Bureau is 18° above zero.

It will be noted that there is double the rainfall in Lombardy that there is in Glenn County, and a large portion of it occurs in the summer, yet irrigation is accepted as decidedly profitable and water rights are increasing in value. This being true, irrigation certainly should be of marked benefit in the Sacramento Valley.

FARMING CONDITIONS.

Glenn County, lying in the upper portion of the Sacramento Valley, and principally upon the western side of the Sacramento River, has so many natural advantages that if its valleys were divided into small farms and irrigated it probably could be made one of the most productive and densely populated agricultural counties in the State of California.

At present the farming land is almost wholly given up to the dry farming of wheat. This practice has been followed for years, until to-day the land, having annually surrendered its nutritive elements, without fertilization, is deteriorating for this crop. This condition, coupled with the low prices obtained for the product during recent years, has resulted in a concentrated landholding, with a resulting decrease of population, large areas of wheat being farmed with greater economy than small ones. This is brought forcibly to the attention of one traveling over the roads in the great valley district. Numerous small bunches of trees mark the points where once stood a house, the home of a small farmer. To-day these families are scattered, and the small ranch is only a small fraction in a great farm of perhaps 10,000 to 20,000 acres, owned by one person and farmed by a drifting population employed only during the planting and harvesting season, and having no interest in the welfare of the county except in obtaining a few weeks' wages, which may or may not be spent in the neighboring towns.

Wheat farming, in spite of the fact that it is carried on by means of modern machinery, with perfect organization, and on a large scale, has not of late been a paying investment in Glenn and adjoining counties.

The climate of this valley is very similar to that of the southern counties of the State. Orange, lemon, and lime trees were seen in various parts of the plains, showing no signs of having been injured by frost. The yield is not large, owing to the fact that the trees have been allowed to grow usually as isolated garden shrubbery, receiving little care except perhaps an occasional watering. With irrigation and scientific care, Glenn County could become the home of numerous small farmers; the population of towns and country would be increased, and a thriving community would exist in the present sparsely settled region.

A. SACRAMENTO VALLEY WHEAT FARM NEAR WILLOWS.

B. TYPICAL RANCH HOUSE ON WHEAT FARM NEAR WILLOWS.

POPULATION.

Intensive farming by irrigation, especially the raising of fruit in California, usually has led to the subdivision of large holdings, both because under these conditions large areas are not successfully handled and because increased land values, resulting from the supply of water, is an inducement for the large landowner to sell.

The census of 1890 gives Colusa County, which at that time included Glenn County, a population of 14,640, while the census of 1900 gives this same territory a population of 12,856 (Colusa 7,346, Glenn 5,510), showing a decrease in the ten years of 12.8 per cent. According to the school census the number of school districts is 38 and the number of school children is 1,280. Of the latter 555 were in the towns, leaving 725 in the country, or only about 1 child to 2 square miles.

In 1891 Mr. William Hammond Hall, in an engineering report on the Central Irrigation District, situated in Glenn County and containing 156,550 acres of valley land, which was then attempting to construct irrigation works, states:

> There are 40 owners of over 1,000 acres each, holding an aggregate of about 89,000 acres, very materially more than half the acreage in this district. There are only about 180 owners of farming lands altogether in it, so that the farm holdings all average very nearly 870 acres in area, and the 140 smaller owners of, say 67,550 acres, have an average of 482 acres apiece. There are but few owners of less than 640 acres in the district, and by reason of the renting and share system still fewer persons who farm as low an acreage. The district has a stable voting population of about 400, of whom about 140 are residents of the towns of Maxwell and Williams. This leaves 260 voters on the farming lands proper, only 1.06 voters, or (taking the usual ratio of voters to population) about 5 persons to the square mile. Each farming landowner of the 180 (supposing all to be residents of the district) gets on with only 0.44 of a resident citizen hired man to help him farm his average holding of 870 acres.

The condition of the Central Irrigation District is practically the condition of the plains district of Glenn and Colusa counties.

Mr. W. H. Markham, deputy assessor of Glenn County, after an examination of the county records in 1900, reports that the average farm-land holding in the plains district, lands which could be irrigated, either from Stony Creek or from the ditches of the Central Irrigation District, is 1,595 acres. There are less than 40 owners of farming lands of 160 acres or less. It is not believed there are any farmers who cultivate less than 320 acres of land, it all being sown to wheat and barley.

For purposes of comparison between areas in California irrigated and those farmed dry, Riverside may be taken as a typical example of development by irrigation. Other similar districts could be referred to. About 13,500 acres are irrigated around Riverside, partly in young trees. It must be remembered that southern California has for seven years been suffering from an intense drought, much more severe than in the central portion of the State. Streams have failed,

but 500 wells have been sunk to supply these lands, from which the water supply has been maintained in volume as large as during periods of abundant precipitation. These wells probably represent an investment of over half a million dollars, and are producing 75 cubic feet of water per second, or enough to irrigate 20,000 acres of land. Starting with a sheep pasture, assessed under protest at 75 cents per acre in 1870, this district now supports in comfort, if not luxury, about 10,000 inhabitants, or a citizen to every 1.3 acres irrigated (about 100 times as dense a population as the valley portion of Glenn County), and shipped over 4,000 carloads of citrus fruits during the season of 1900. The value of this crop was $150 per acre on the better irrigated area, and the output is rapidly increasing. The city of Riverside has 3 banks, 13 churches, and 8 schoolhouses. The post-office receipts in 1900 were $16,555. The amount of its bank deposits and assessed valuation make it perhaps the first city of its class in the United States.

From an agricultural standpoint the difference between northern and southern California is irrigation.

CENTRAL IRRIGATION DISTRICT.

In the course of the present work the constructed portion of the Central Irrigation canal was visited and inquiries were made as to its status. This canal was designed to take water from the Sacramento River near the northern boundary of Glenn County and irrigate 156,550 acres of fertile land in Glenn and Colusa counties. After expending $574,000 for construction and right of way, the district became involved in legal and financial difficulties growing out of the Wright act, under which it was organized, and work was discontinued. Both the constitutionality of the organic law and the organization under that law were contested by certain dissatisfied holders of large land areas in the proposed district. These parties objected to an organization based upon and controlled by a majority vote of all electors in the district, irrespective of their property holdings therein, the acceptance of water at uniform rates for all lands in the district being compulsory under the law. These objections have been brought forward in all the districts that have been organized under this statute.

No successful attempt has ever been made to collect either principal or interest on these bonds. The interest is increasing and the principal is becoming due. Much money has been spent by both "anti-irrigationists" and "irrigationists" in legal battles, but so far no definite result, except the stoppage of work for lack of funds, has been accomplished. The headworks of the canal were never built and no water has ever been delivered. The bonds are discredited in the financial market, and if the district should now be declared to be legal and the bonds properly issued it will force nearly every farmer in the district into bankruptcy, as it has been twelve years since the

OPPOSITE WILLOWS

ere issued. The bondholders are getting no interest on their ent and the landholders are going on year after year summer g their land for wheat, and barely making interest on a low n of the land and property, while right at hand flows the nto River, capable of turning this valley into as productive sely populated a county as the irrigated portions of southern ia counties.

acramento River has an unfailing supply of water sufficient he needs of this section and of the lower valley lands, as is y the following table of flow, taken from the various reports nited States Geological Survey.

stimated monthly discharge of Sacramento River at Red Bluff.

[Drainage area, 9,356 square miles.]

h.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
5.						
.....	123,000	15,220	47,267	2,906,320	5.05	5.82
.....	65,600	13,860	26,792	1,487,940	2.86	2.98
.....	85,360	15,220	32,517	1,999,418	3.48	4.01
.....	33,880	26,670	29,566	1,759,300	3.16	3.53
.....	48,600	16,840	30,238	1,859,250	3.23	3.73
.....	18,600	9,040	12,764	759,510	1.36	1.52
.....	9,040	6,150	7,235	444,863	.77	.89
.....	6,150	5,990	6,057	372,436	.65	.75
er	10,820	5,830	6,321	376,106	.68	.75
.....	6,285	5,910	5,989	368,261	.64	.74
er	6,690	5,910	6,046	359,792	.65	.71
r	36,880	6,150	10,095	620,760	1.08	1.24
e year .	123,000	5,830	18,390	13,313,956	1.97	26.67

Estimated monthly discharge of Sacramento River at Jellys Ferry, Tehama County.

[Drainage area, 9,134 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.						
January	130,050	6,360	46,152	2,837,813	5.05	5.86
February	34,460	10,070	15,468	889,764	1.69	1.82
March	62,870	11,310	24,099	1,481,801	2.64	3.05
April	59,500	16,920	25,793	1,534,819	2.82	3.14
May	75,120	19,300	30,941	1,902,543	3.39	3.91
June	20,515	9,200	14,217	846,018	1.56	1.74
July	8,960	6,720	7,591	466,789	.83	.95
August	6,720	6,180	6,394	393,201	.70	.81
September	6,360	6,000	6,204	369,163	.68	.75
October	8,000	6,000	6,163	378,960	.67	.77
November	43,000	6,360	11,965	712,014	1.31	1.46
December	93,000	8,480	22,318	1,372,304	2.44	2.82
The year	130,050	6,000	18,109	13,185,189	1.98	27.08
1897.						
January	49,765	8,320	14,280	878,050	1.56	1.80
February	89,100	17,420	36,108	2,005,335	3.95	4.11
March	44,340	13,100	21,790	1,339,825	2.39	2.76
April	28,710	18,830	22,807	1,357,108	2.50	2.79
May	18,520	9,200	13,737	844,660	1.50	1.73
June	9,200	6,680	7,620	453,420	.83	.92
July	6,550	5,120	5,699	350,420	.62	.71
August	5,120	4,600	4,776	293,667	.52	.60
September	4,600	4,600	4,600	273,718	.50	.56
October	6,680	4,600	4,955	304,673	.54	.62
November	8,600	5,120	5,590	332,627	.61	.68
December	16,940	5,380	7,792	479,114	.85	.98
The year	89,100	4,600	12,480	8,912,617	1.36	18.36
1898.						
January	6,525	5,835	6,120	376,307	.67	.77
February	33,600	5,835	12,479	693,049	1.37	1.43
March	22,500	6,525	9,745	599,201	1.07	1.23
April	7,260	6,525	6,872	408,911	.75	.83
May	10,800	5,375	6,632	407,789	.73	.84
June	10,500	5,150	6,674	397,130	.73	.81
July	5,150	4,475	4,700	288,994	.52	.60

A. CENTRAL IRRIGATION DISTRICT CANAL OPPOSITE JACINTO.

B. CENTRAL IRRIGATION DISTRICT CANAL NEAR ST. JOHNS.

ted monthly discharge of Sacramento River at Jellys Ferry, Tehama County—Continued.

th.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
8.						
.....	4,475	4,250	4,276	262,923	0.47	0.54
er	4,475	4,250	4,280	254,677	.47	.53
.....	4,925	4,475	4,631	284,751	.51	.59
er	6,892	4,475	4,785	284,727	.52	.58
r	5,950	4,700	4,991	306,887	.55	.63
e year .	33,600	4,250	6,349	4,565,346	.70	9.38
9.						
.....	42,600	5,065	13,498	829,965	1.48	1.71
r	8,644	5,810	6,646	369,100	.73	.76
.....	83,400	6,750	20,915	1,286,022	2.29	2.64
.....	16,100	7,800	10,837	344,845	1.19	1.33
.....	7,530	6,030	6,908	424,759	.76	.87
.....	15,200	4,965	6,199	365,865	.68	.75
.....	4,760	4,170	4,531	278,592	.50	.58
.....	4,170	3,980	3,986	245,061	.44	.51
er	3,980	3,980	3,980	236,826	.44	.49
.....	10,550	3,980	5,063	311,314	.55	.63
er	53,480	4,760	14,532	864,712	1.59	1.77
r	45,600	8,915	14,519	892,744	1.59	1.83
e year .	83,400	3,980	9,301	6,752,805	1.02	13.87
0.						
.....	119,700	10,400	30,661	1,885,271	3.36	3.88
r	24,800	7,800	11,687	649,063	1.28	1.33
.....	123,000	10,700	23,288	1,431,923	2.55	2.94
.....	16,700	8,630	12,082	718,929	1.32	1.47
.....	19,780	6,265	9,572	588,559	1.05	1.21
.....	6,265	4,760	5,477	325,904	.60	.67
.....	4,760	3,805	4,212	258,986	.46	.53
.....	3,805	3,805	3,805	233,960	.42	.48
er	5,170	3,630	3,981	236,886	.44	.49
.....	21,520	3,805	6,381	392,352	.70	.81
er	28,800	4,560	8,205	488,231	.90	1.00
r	80,100	6,030	15,553	956,317	1.70	1.96
e year .	123,000	3,630	11,242	8,166,381	1.23	16.77

Estimated monthly discharge of Sacramento River at Jellys Ferry, Tehama County—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.						
January	74,240	8,915	20,982	1,290,194	2.30	2.66
February	101,880	9,800	34,138	1,895,928	3.74	3.89
March	46,100	12,200	20,628	1,268,366	2.26	2.61
April	16,700	9,200	10,870	646,810	1.19	1.33
May	13,700	7,530	9,804	602,824	1.07	1.23
June	7,265	4,965	5,596	332,985	.61	.68
July	4,760	3,980	4,365	268,393	.48	.55
August	3,980	3,805	3,850	236,727	.42	.48
September	5,380	3,630	3,922	233,375	.43	.48
October	5,380	3,980	4,194	257,879	.46	.53
November	44,100	4,360	7,745	460,859	.85	.94
December	61,800	5,380	12,149	747,013	1.33	1.53
The year	101,880	3,630	11,521	8,241,353	1.26	16.91

Estimated monthly discharge of Sacramento River at Iron Canyon, Tehama County, Cal.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.						
January [a]	6,750	4,760	5,376	330,557	0.59	0.68
February	151,320	5,660	69,153	3,840,563	7.44	7.75
March	61,700	14,150	27,371	1,682,977	2.94	3.39
April	53,800	14,150	21,992	1,308,615	2.37	2.64
May	24,460	10,150	17,803	1,094,663	1.92	2.21
June	13,450	7,060	9,998	594,922	1.08	1.20
July	7,060	5,880	6,192	380,731	.67	.77
August	5,880	5,440	5,674	348,881	.61	.70
September	5,220	5,000	5,007	297,938	.54	.60
October	11,750	5,000	5,931	364,683	.64	.74
November	118,200	5,660	19,834	1,180,204	2.13	2.38
December	39,100	8,110	17,506	1,076,402	1.88	2.17
The year	151,320	4,760	17,653	12,501,136	1.90	25.23

[a] Record of Sacramento at Jellys Ferry for January, 1902.

POSSIBLE REORGANIZATION OF CENTRAL IRRIGATION DISTRICT.

It is believed that the present time is auspicious for the carrying ›ut of a reorganization plan. The question of the legality or illegality ›f the district's organization and bond issues has not yet been finally letermined, and neither party seems willing to push the matter to a inal issue.

If it is desirable to complete the works under private management, ; is believed that the following plan might be carried out: The dis- rict to acquire what rights of way are necessary for the completion f the work. This probably can be done for about $30,000. The dis- rict should then deed to the bondholders its interest in the canal and ights of way and then disorganize, the bondholders canceling all ıdebtedness against the land and furnishing the money to complete ıe works. The bondholders could then form an irrigation company nd sell water at the low annual charge of $2 per acre, and thereby oth secure themselves and benefit the landowners. The land is ertile and suited to irrigation, and, owing to its closeness to market, ıould be high priced and productive of handsome returns.[a]

TOPOGRAPHY.

The purpose of the present work was primarily to determine what ›uld be done toward increasing the area of lands irrigated from the asin of Stony Creek. Stony Creek has a drainage area of about 760 quare miles, as obtained from the best available Land-Office maps. Vhile the crest of the watershed does not exceed about 6,700 feet in evation, its proximity to the coast assures to it a substantial amount f rainfall. In the valleys the precipitation is 20 inches annually, hile in the higher portions of the basin it probably reaches 40 inches. he summits are heavily covered with timber, much of it being com- ıercial pine, spruce, and cedar. Several sawmills are located in the eart of this timbered area. Sheep, goats, and cattle are permitted eely to graze over the public lands, and numerous forest fires were bserved, apparently coincident with the location of the grazing ımps. It is currently stated that it is the common practice for sheep en to set fires upon leaving the ranges in the fall so that the under- rush and grasses can grow up young and tender for the next season. attlemen, finding heavily brushed areas over which it is difficult for ıe cattle to graze, are reported to set fires so as to make the country ore open. The resulting damage does not apply alone to the brush- ›vered territory, as the fires, once started, keep on burning, unre- rained, into the timber belts, until a continued wind from the ›ntrary direction causes the flames to back fire and extinguish

[a] Since the above was written (1901) a strong movement has been initiated to disorganize the strict and to have a corporation complete the canal and distribute the water, the bonded debt be assumed by the corporation.

themselves. If this forest destruction continues, it will cause the run-off to be more spasmodic, floods will closely follow each rain, and the amount of silt carried by the water will become so great that it would lead to the impairment of any reservoirs which might be constructed in this basin. It is strongly urged that the main portion of this drainage basin be set aside as a forest reserve, and that sheep and goat grazing be restricted or prohibited, and strong steps taken to prevent forest fires.

PROPOSED STONY CREEK FOREST RESERVE.

In respect to this matter the Sacramento Valley Development Association, on November 17, 1900, passed the following resolution as a result of the investigations on the stream:

Whereas the experts of the United States Geological Survey now conducting investigations along Stony Creek report the existence of many excellent storage-reservoir sites thereon; and

Whereas the waters of said creek are now used for irrigation, and by their conservation and proper regulation a vast area may be brought to a much higher state of cultivation; and

Whereas the preservation of the forests along the headwaters of said creek is necessary to insure a permanent water supply and also to moderate the flow of flood waters, thereby preventing the rapid filling with silt and detritus of any reservoirs that may hereafter be constructed along said Stony Creek or any of its tributaries: Therefore be it

Resolved, That we, the Sacramento Valley Development Association, earnestly petition the President of the United States to set aside as a forest reserve such of the public lands about the head of said Stony Creek and its tributaries as the experts of the Geological Survey shall recommend as necessary for the protection of the water supply of said creek.

Adopted at a meeting of the Sacramento Valley Development Association held in Oroville, Cal., November 17, 1900.

Practically the same resolutions were also passed by the Water and Forest Association.

In response to the above requests the following area has been temporarily withdrawn from entry, August 14, 1900, pending investigation by the Bureau of Forestry:

Beginning at the northwest corner of T. 23 N., R. 6 W., Mount Diablo meridian; thence south to the northwest corner of T. 20 N., R. 6 W., Mount Diablo meridian; thence west on township line to northwest corner of sec. 2, T. 20 N., R. 7 W.; thence south to southwest corner of sec. 26, township and range aforesaid; thence east to northwest corner of sec. 36, township and range last aforesaid; thence south 1 mile; thence east to northeast corner of T. 19 N., R. 7 W., Mount Diablo meridian; thence south on range line 3 miles to southwest corner of sec. 18, T. 19 N., R. 6 W.; thence east to northeast corner of sec. 19, T. 19 N., R. 6 W. thence south to southeast corner of sec. 31, said township and range aforesaid; thence west to northwest corner of T. 18 N., R. 6 W.; thence south on range line between

Rs. 6 and 7 W., to southwest corner of sec. 6, T. 17 N., R. 6 W.; thence east to northeast corner of sec. 8, township and range last aforesaid; thence south to southeast corner of sec. 32, T. 16 N., R. 6 W.; thence west on township line between Ts. 15 and 16 N., to southwest corner of T. 16 N., R. 10 W.; thence north on range line between Rs. 10 and 11 W., to northwest corner of T. 23 N., R. 10 W.; thence easterly to northwest corner of T. 23 N., R. 6 W., the place of beginning.

Local stock and lumbermen are now (1903) violently opposing the creation of this and other proposed reserves in the basin of the Sacramento River. It is believed that this is largely done because the true purpose of forestry is not understood.

A forest reserve is created for the permanent benefit and ultimate improvement of the district wherein it exists. These benefits may be divided into two classes: First, forestry; second, irrigation. There are some good timbered lands on the headwaters of Stony Creek and the crest of the range immediately to the west. Under the ordinary methods of procedure a lumber company entering into business in a timbered district will cut off the entire forest cover as rapidly as possible, sell the product, clean up its business, and get out of the country, leaving the district in a denuded and wrecked condition. This is so abundantly evident in so many different localities in California that it is scarcely necessary to enter into an extended argument as to its impropriety. The county is a permanent loser, because when these lands are once cut off they are usually abandoned to the State because of delinquent taxes. There is no permanent employment offered for citizens of the community, and the result is a rapid wrecking of the forest.

The effect on the State of reckless deforestation is the destruction of a permanent source of lumber supply. This method of procedure has led to the marked deterioration of many of the older countries. The policy advocated for the Federal Government is that looking toward a continuous use of the forest as a permanent source of lumber supply along lines of development now practiced by England in India, by France, Germany, Sweden, and other European countries. With this method only the matured or ripened tree is cut off. The younger trees are protected and saved. The policy is distinctly one for the continued utilization of the forest and not for its destruction. Again, by far the greatest enemy of forests is fire, and with the creation of a forest reserve there will be provided guards to prevent these fires and fight them when they are once started. The general effect on the nation and State is to furnish a permanent lumber crop for the development of towns and cities.

The forest is a great natural regulator of the waters used in irrigation. A stream proceeding out of a denuded area becomes a violent torrent immediately following a storm, washing great gullies in the

sides of the hills, carrying down débris and stones, and depositing them on the valleys and lowlands. The stream in the summer time dries up, and a condition of desolation is an almost inevitable result. If storage reservoirs are built upon such a stream the tendency is to rapidly fill them with débris. An engineer could scarcely recommend the construction of a reservoir on any of the branches of Stony Creek if the drainage basin above it were denuded.

Stony Creek presents great natural opportunities for the regulation of storm waters. Surveys made for sites by the Geological Survey show that the construction of reservoirs is commercially feasible. The climatic conditions along the foothills are such as to permit, with irrigation, the raising of any crop that is grown in the State of California. It is believed that the day is not distant when these reservoirs will be built, when the foothill land will be under cultivation, when the products therefrom will be as valuable as from any portion of the State, and when the population on these lands will approach an inhabitant to each 2 acres.

Glenn County is confronted to-day with a decreasing population and a decreasing assessed valuation, as a result of efforts at dry farming. With natural opportunities greater than any that exist in southern California it has not reached 1 per cent of the development which is possible. It is believed that the day will come when this development will occur, and when the conservation of the stream will be the basis of its successful maturing. It would, therefore, seem to be ill-advised for the county to oppose the creation of a forest reserve which looks toward the development of such a condition as that suggested, particularly as the only compensation which would be received therefrom would consist in furnishing pasture for a few thousand sheep and goats, which would range over the hills of the back country.

The forest-reserve policy is not hostile to stockmen. It would oppose such unrestricted overstocking and burning off of mountain sides as is now being practiced in the drainage basin of Stony Creek. In the forest reserves of other portions of the United States where the trees are mature, and where, after careful study, the conclusion has been reached that stock will not injure the reserve, they have been permitted to range therein under proper regulations and restrictions and particularly with safeguards against fires. Cattle range throughout the forest reserves of the Sierra Nevada. In selecting the persons who may range stock in these districts, preference is always given to local residents. It is absurd to claim that this forest reserve is being presented and promoted by large corporate interests for their selfish advantage. On the other hand, it is recommended and indorsed by many of the most intelligent and far-seeing men of California and of the United States.

A. BLACK BUTTE.

B. STONY CREEK GAGING STATION.

PRECIPITATION AND CLIMATE.

Rainfall records in Stony Creek Basin above the proposed points of npounding the flood waters are very meager and fragmentary.

A record at Fouts Springs, in the watershed of Little Stony Creek, as been furnished by John F. Fouts and S. E. Sites for three seasons, nd partial records for two other years. There is also a short record t Little Stony, in the same basin. A rain gage was placed at Julian's anch house on main stream, February, 1901, at the time the gaging tation was established. These records are the only ones available irectly in the watersheds tributary to the proposed reservoirs. Recrds for several points outside of the basin are given as being typical f the rainfall at the higher elevations of the watershed. These are Bartlett Springs, on the North Fork of Cache Creek, which adjoins the vatershed of Little Stony on the south; Camp Wright, which is situted a few miles west of the crest of Stony Creek watershed; and Veaverville, which is several miles north of the basin.

The records of precipitation at Red Bluff, at the head of Sacramento alley; at Jacinto, which is situated on the Sacramento River 14 miles utheast of Orland; and at Woodlands, have been selected as typical the rainfall in the valley lands to be irrigated from the stored waters Stony Creek.

Precipitation, in inches, at Bartlett Springs, Lake County.

[Latitude, 39° 10′; longitude, 122° 45′; elevation, 2,375 feet; authority, J. E. McMahon.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
7	.....	.....	.....	.....	3.50	6.78	5.36	0.75	0	0	0	0	16.39
7-98	0	1.70	2.31	3.72	1.53	8.36	.19	.63	2.39	1.10	0	0	21.93
8-99	0	0	1.87	1.23	13.14	0	8.49	.85	2.47	0	0	0	28.05
9-1900	0	4.79	10.06	7.87	7.51	1.27	6.42	3.23	.88	0	0	0	42.03
0-1901	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1-2	1.17	1.80	5.86	4.02	1.71	22.38	5.98	5.20	3.40	0	0	0	51.52
2-3	0	5.97	11.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Precipitation, in inches, at Fouts Springs, Colusa County.

atitude, 39° 20′; longitude, 122° 40′; elevation, 1,650 feet; authority, John F. Fouts and S. E. Sites.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
5-86	(0)	0.20	19.43	4.85	9.29	2.00	1.65	5.01	0.50	T.	0	0	42.93
6-87	0	.70	.20	2.83	2.00	7.88	2.12	1.66	T.	T.	T.	0	17.39
7-88	T.	0	1.25	4.35	10.83	70	5.00	3.34	2.14	0.65	(0)	(0)	28.25
Mean	0	.30	6.96	4.01	7.37	3.53	2.92	3.34	.88	.22	0	0	29.52
2-93	.....	.....	.....	.....	2.08		5.17	1.95	.....	.....	.....	.....	[a]16.31
0-1901	.....	.....	.....	5.41	12.57	4.06	.....	.79	.....	.....	.....	.....	[a]22.83

[a] Year incomplete.

Precipitation, in inches, at Little Stony, Colusa County.

[Latitude, 39° 25′; longitude, 122° 30′; authority, C. M. Polley.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1884–85	.....	.....	.....	8.40	1.29	1.04	0	1.38	0	1.19	0	0	[a]13.30
1885–86	0	0.27	13.29	3.51	3.44	0	1.10	3.89	.....	.....	.....	.....	[a]25.50

[a] Year incomplete.

Precipitation, in inches, at Julian's ranch, on Stony Creek, Glenn County.

[Latitude, 39° 35′; longitude, 122° 30′; elevation, 750 feet; authority, Mrs. Lee Julian.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1900–1901	.....	.....	.....	.....	.....	4.26	0.12	1.24	0.50	0	0	0	[a]6.12
1901–2	1.07	0.60	3.18	0.82	0.85	9.27	3.24	2.37	2.06	0	0	0	23.46

[a] Year incomplete.

Precipitation, in inches, at Camp Wright, Mendocino County.

[Latitude, 39° 45′; longitude, 123°; elevation, 1,800 feet; authority, U. S. War Department.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1864–65	0.03	0.85	6.19	12.20	3.64	4.88	3.57	0.36	0.43	0	0	0	32.15
1865–66	.81	.87	16.67	2.05	15.83	4.30	11.80	1.05	.....	.....	.....	.....	[a]53.38
1866–67	0	0	5.92	24.67	8.92	7.85	2.38	3.10	.01	0	0	0	52.85
1867–68	1.56	3.75	6.38	29.03	8.61	5.89	9.11	3.25	.71	1.58	0	0	69.87
1868–69	.05	.25	2.79	6.63	13.57	4.13	3.80	4.51	.55	0	0	0	36.28
1869–70	1.42	.84	5.38	8.06	7.03	6.61	2.40	2.02	.39	0	0	0	34.15
1870–71	0	0	1.28	1.19	2.66	4.60	7.10	1.07	1.96	0	0	0	19.86
1871–72	.50	.31	4.03	16.64	11.52	19.78	5.34	.66	.12	.04	0	0.20	59.14
1872–73	0	.36	5.20	7.24	3.55	6.92	2.91	1.13	.04	.30	0.10	0	27.75
1873–74	.05	.34	4.98	15.50	12.94	5.46	7.26	3.72	1.16	.26	.01	0	51.68
1874–75	0	5.61	12.90	2.27	9.83	1.06	1.76	.59	2.32	0	0	0	36.43
Mean	.40	1.20	6.53	11.41	8.92	6.50	5.22	1.95	.77	.20	.01	.02	43.13

[a] Year incomplete.

Precipitation, in inches, at Weaverville, Trinity County.

[Latitude, 40° 46′; longitude, 123° 25′; elevation, 2,162 feet; authority, George E. Noonan.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
869-70	1.06	1.03	8.01	6.15	10.11	9.64	2.05	1.06	0.22	0	0	0	39.33
870-71	.64	1.39	6.41	9.43	8.16	11.19	3.02	1.73	1.03	0.14	0	0	43.14
871-72	.29	.40	11.50	3.52	19.62	15.09	3.11	2.43	.84	.17	0	0.25	57.22
872-73	.35	.78	3.01	6.32	6.51	4.29	2.78	.50	.27	0	0	0	24.81
873-74	1.80	4.39	4.02	9.57	15.40	4.41	3.12	3.58	2.67	.70	0	0	49.66
874-75	0	1.57	10.30	1.32	6.59	.46	2.14	.19	1.22	.93	0	0	24.72
875-76	0	2.82	15.39	11.94	9.69	9.49	8.23	2.79	1.63	.15	0.47	0	62.60
876-77	.67	7.38	1.50	.29	6.27	6.24	4.52	2.26	1.62	1.72	.02	0.21	32.70
877-78	0	1.83	8.72	6.50	19.83	16.20	8.53	2.42	1.07	.07	.02	.03	65.22
878-79	1.28	1.80	3.58	4.91	2.02	6.48	12.84	4.05	4.02	.68	.02	.03	41.71
879-80	.03	2.08	8.09	13.20	6.64	2.59	4.72	10.78	1.46	.23	.38	.36	50.56
880-81	0	.55	1.49	14.14	18.61	11.05	1.21	3.13	1.15	.99	0	0	52.32
881-82	.93	3.77	2.58	8.00	4.19	6.90	3.62	2.44	1.29	0	0	0	33.72
882-83	1.38	8.36	.78	5.05	4.46	1.50	3.24	5.00	3.72	0	0	0	33.49
883-84	.88	2.45	1.50	4.97	8.81	3.56	5.10	6.29	1.60	2.93	.13	0	38.22
884-85	.44	.11	16.56	6.78	3.68	3.70	.15	2.78	.51	1.41	0	0	36.12
Mean	.61	2.54	6.47	7.15	9.41	7.05	4.27	3.21	1.52	.63	.07	.05	42.84

Precipitation, in inches, at Jacinto, Glenn County.

[Latitude, 39° 35′; longitude, 122°; elevation, 110 feet.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
892-93	.....	.....	6.32	8.13	4.20	2.99	3.71	0.87	1.44	0	0	0	29.49
893-94	0.47	0.06	2.67	1.61	4.50	1.47	.89	.51	1.24	0	0	0	13.42
894-95	1.20	1.33	.35	8.69	8.73	1.86	1.74	2.49	.22	0	.36	0	26.97
895-96	2.33	0	1.10	.94	9.37	.24	2.92	4.03	.69	0	0	.52	22.14
896-97	.63	.68	3.06	5.28	3.78	3.54	1.72	.77	.60	.44	0	0	20.50
897-98	0	2.12	1.16	1.40	.76	3.42	.31	2.07	0	0	0	0	11.24
898-99	.35	.41	.49	1.39	6.36	0	4.29	.36	1.21	.53	0	0	15.39
899-1900	0	2.68	4.40	3.40	3.06	.17	1.27	1.68	.72	0	0	0	17.38
900-1901	0	2.42	5.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	[a] 7.42
Mean	.62	1.21	2.72	3.85	5.09	1.71	2.11	1.59	.76	.12	.04	.06	18.22

[a] Year incomplete.

Precipitation, in inches, at Woodlands, Yolo County.

[Latitude, 38° 42′; longitude, 121° 47′; elevation, 63 feet; authority, O. P. Co., 1878–1899, and Elston drug store, 1894–1899.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1878	.....	.....	.....	.....	8.17	8.36	3.83	1.47	0.65	0	0	0	22.48
1878–79	0.17	0.22	0.89	0.42	3.03	3.20	4.74	1.91	1.68	0.24	0	0	16.50
1879–80	0	.21	2.09	3.69	1.04	1.60	.93	6.96	.35	0	0	0	16.87
1880–81	0	0	.06	8.77	4.94	1.86	1.05	1.53	0	.33	0	0	18.54
1881–82	0	.37	2.08	2.25	.89	1.88	1.89	1.37	0	0	0	0	10.73
1882–83	.59	1.38	2.40	.51	1.98	.45	3.13	1.23	4.12	0	0	0	15.79
1883–84	.44	1.03	.29	.29	3.47	3.24	4.69	3.83	0	0	0	0	17.28
1884–85	0	1.00	0	4.63	1.43	.12	.10	1.44	0	0	0	0	8.72
1885–86	0	.20	8.70	3.75	4.78	0	1.31	4.10	0	0	0	0	22.84
1886–87	0	0	0	1.29	.80	5.58	.65	1.53	0	0	0	0	9.86
1887–88	0	0	.40	3.30	4.20	1.27	2.38	.10	1.10	0	0	0	12.75
1888–89	.56	0	5.57	4.97	0	.55	6.21	.62	1.46	.35	0	0	20.29
1889–90	0	5.32	3.75	8.48	5.10	2.40	3.35	1.00	1.60	0	0	0	31.00
1890–91	.60	0	0	2.35	.82	8.08	.35	1.17	.43	0	0	0	13.80
1891–92	0	0	.40	3.10	2.05	2.73	2.14	1.28	2.22	0	0	0	13.90
1892–93	0	.57	5.47	6.10	2.88	2.78	2.00	.62	.61	0	0	0	21.03
1893–94	0	.08	1.71	1.92	4.12	2.15	.88	.42	1.49	.77	0	0	13.54
1894–95	.85	1.12	.85	10.82	9.83	1.28	.91	.52	.45	0	0	0	26.63
1895–96	1.37	.19	1.69	.90	11.87	.11	2.08	6.73	.76	0	0	0.35	26.05
1896–97	.50	1.27	3.76	2.03	3.32	5.21	2.75	.25	.29	.09	0	0	19.67
1897–98	.02	1.81	.56	.72	.43	3.35	.12	.21	1.38	.18	0	0	8.78
1898–99	.35	.98	.47	1.53	5.67	.14	14.46	.13	.08	.78	0	0	24.59
1899–1900	0	3.55	3.01	3.53	2.14	.40	1.20	.96	.54	0	0	0	15.33
1900–1901	0	1.46	5.17	1.22	3.26	5.39	.51	1.91	.71	0	T.	0	19.63
1901–2	0	.90	4.21	.92	.34	6.52	2.01	1.25	.57	.40	0	0	17.12
Mean	.23	.90	2.23	2.81	3.46	2.74	2.54	1.70	.82	.13	0	.01	17.74

NOTE.—The figures for the years 1894 to 1899, inclusive, are the mean of two records.

Mean monthly and annual temperature, in degrees Fahrenheit, at Fruto, Glenn County.

[Elevation, 295 feet.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean annual.
1888–89	83.3	70.9	57.4	49.7	47.3	52.0	58.6	64.0	70.3	84.7	84.5	84.5	.....
1889–90	82.9	63.5	58.2	48.9	41.6	48.3	52.9	62.3	71.2	.....	.....	.....	.....

ean monthly and annual temperature, in degrees Fahrenheit, at Willows, Glenn County.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	54.0	45.5	.....
.....	42.9	52.3	56.9	62.5	66.1	82.2	84.1	84.6	77.5	63.1	50.3	43.3	63.8
.....	42.7	45.2	48.9	57.4	67.5	77.2	86.4	80.3	75.5	66.6	50.5	50.1	62.2
.....	49.2	52.3	55.1	66.1	74.7	[77.4]	86.4	77.2	75.7	58.2	51.4	46.5	[64.2]
.....	43.6	41.8	53.6	57.8	72.4	82.7	88.3	84.5	78.2	64.9	58.2	43.9	64.2
.....	37.3	46.5	62.0	63.8	70.1	[77.4]	85.8	81.9	81.1	63.8	55.2	45.4	[64.2]
.....	47.4	46.0	58.9	53.2	64.7	76.6	78.2	79.6	68.1	62.4	57.2	45.2	61.5
.....	45.2	47.2	65.8	65.0	71.6	73.1	79.2	81.9	76.9	69.0	51.0	50.5	64.7
.....	44.1	53.1	52.3	55.6	67.5	81.1	82.7	83.1	80.0	64.2	52.9	51.0	64.0
.....	50.0	45.7	60.2	64.7	73.1	80.0	86.3	87.0	78.4	71.7	56.0	46.3	66.6
.....	40.3	51.1	51.6	64.1	67.2	70.9	79.8	78.8	84.2	67.8	52.5	47.6	63.0
.....	42.9	47.6	51.8	59.7	67.9	80.3	82.2	79.7	74.7	60.7	53.0	46.6	62.3
.....	42.2	47.4	49.9	57.7	69.3	69.6	.....	.....	.....	.....	.....	.....	.....
Mean....	44.0	48.0	55.6	60.6	69.3	77.4	83.6	81.7	77.3	64.8	53.5	46.8	63.6

ean monthly and annual temperature, in degrees Fahrenheit, at Woodlands, Yolo County.

[Elevation, 63 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual.
6.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	53.9	46.6	.....
7.....	49.7	54.6	60.9	61.7	65.7	77.1	80.1	76.1	74.7	59.9	54.9	48.6	63.7
78.....	48.7	50.7	56.4	61.6	67.4	75.4	76.0	75.7	68.4	63.2	54.5	45.3	61.9
79.....	44.4	54.3	57.7	61.7	64.3	76.0	78.4	79.6	74.6	64.6	53.3	45.0	62.8
80.....	44.9	47.2	50.0	56.3	65.2	73.3	78.7	76.2	72.9	65.9	52.7	51.6	61.2
81.....	50.4	55.3	53.4	64.1	70.8	75.0	88.8	77.0	74.3	64.1	51.0	49.2	64.4
82.....	46.1	45.4	52.7	61.0	72.3	74.7	79.9	76.4	72.5	60.8	50.9	48.9	61.8
83.....	42.3	47.0	56.4	58.1	65.9	79.4	78.8	75.5	75.5	63.2	54.7	42.0	61.6
84.....	46.5	45.6	54.2	56.1	66.5	69.3	79.2	80.1	72.1	68.6	59.0	51.1	62.4
85.....	47.7	55.4	63.6	65.5	72.9	68.5	74.7	77.5	73.8	67.6	[55.2]	53.0	[64.6]
86.....	48.1	55.3	57	61.5	70.8	78.4	80.2	78.6	71.7	55.5	53.3	51.1	63.5
87.....	49.2	47.6	60.8	62.0	70.0	81.6	82.8	78.6	77.1	78.1	68.1	51.9	67.3
88.....	43.2	46.1	48.	51.7	62.5	67.3	73.4	76.1	74.6	68.8	58.3	50.1	60.0
89.....	44.0	46.5	54.0	59.9	65.9	72.1	75.8	71.8	70.9	58.9	53.3	49.0	60.2
90.....	41.2	45.6	50.9	59.4	63.8	70.7	.....	.....	.....	.....	.....	.....	.....
Mean....	46.2	49.8	55.4	60.0	67.4	74.2	79.0	76.9	73.3	64.6	55.2	48.8	62.6

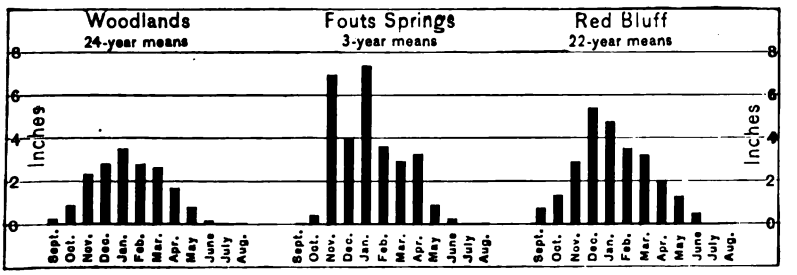


FIG. 1.—Mean monthly precipitation at Woodlands, Fouts Springs, and Red Bluff.

Climatological data for Corning, Orland, and Willows, three points within or close to the land that would be irrigated from the water stored in the Stony Creek Basin, are given for the years 1897 to 1901, inclusive:

Climatological data for Corning, Orland, and Willows.

Stations.	Counties.	Elevation.	Year.	Temperature (degrees Fahrenheit).					Precipitation (inches).				Rainy days.	Sky.			Prevailing direction of wind.
				Annual mean.	Highest.		Lowest.		Total for year.	Greatest monthly.	Month.	Total snowfall.		Clear days.	Partly cloudy days.	Cloudy days.	
					Degrees.	Date.	Degrees.	Date.									
Corning	Tehama	277	1897	61.2	110	Aug. 19	27	Dec. 22	16.54	5.69	Feb.	0	...	...	...	...	...
			1898	59.7	112	June 25	23	Dec. 11	.....	....	.....	5	...	200	0	165	S.
			1899	62.2	110	July 18	25	Feb. 4	27.72	8.13	Jan.	0	44	228	0	137	N.
			1900	63.1	110	July 19	32	Dec. 31	21.55	4.61	Jan.	0	51	213	8	144	N.
			1901	63.8	108	June 28	26	Jan. 1	20.66	6.09	Jan.	3.5	41	227	0	138	N.
Orland	Glenn	254	1897	64.9	110	Aug. 19	27	Dec. 22	14.14	4.01	Feb.	0	...	...	...	...	...
			1898	65.6	118	Aug. 12	26	Jan. 12	7.93	3.64	Feb.	0	25	229	4	132	N.
			1899	64.4	115	July 19	26	Feb. 4	22.41	6.98	Jan.	0	65	195	3	167	N.
			1900	62.0	112	...do	29	Dec. 31	18.40	4.61	Nov.	0	60	200	1	164	N.
			1901	65.0	116	Aug. 3	24	Jan. 1	17.86	5.14	Feb.	1	40	...	...	...	N.
Willows	...do	132	1897	....	105	June 30	32	Dec. 20	10.85	4.26	Feb.	0	...	...	...	...	...
			1898	64.8	112	Aug. 12	30	Dec. 30	6.94	2.46	Feb.	0	20	273	4	88	N.
			1899	63.0	115	July 24	32	Feb. 2	19.15	6.56	Jan.	0	46	250	0	115	N.
			1900	66.3	105	July 7	35	Dec. 31	14.28	4.37	Nov.	0	42	233	9	123	N.
			1901	67.2	109	Aug. 3	30	Jan. 1	16.54	3.88	Feb.	0	39	255	0	110	N.

On page 4 of the California section of the Climate and Crop Bulleti of the Weather Bureau for November, 1900, is an excellent and mo complete collection of data, compiled by Maurice Connell, observe which are given in full as fairly representing the climatic conditio of the territory on the west side of the Sacramento Valley in th vicinity of Willows, Orland, and Corning.

Red Bluff is the county seat of Tehama County, at the northern en of the Sacramento Valley. The city is situated on the western ban of the Sacramento River, in latitude 40° 10′ north, longitude 122° 1 west, the average elevation above sea level being 309 feet. The lan slopes gently to the river, and within a radius of 5 miles the count is comparatively flat. The general movement of the air is from th north and northeast into the valley from the mountains on the nor and east. During the summer months, however, there is a wel marked northerly movement of the air, which is in part due to th strong westerly indraft through the Golden Gate and its subseque deflection northward through the valley. The highest temperatu recorded is 114° and the lowest 18°. The average annual precipit *tion is 25.56* inches.

ly and annual mean temperature at Red Bluff, Cal., in degrees Fahrenheit, with departures from normal.

r.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Departure from normal.
.....	47.3	50.2	55.5	60.4	67.4	81.0	81.6	83.2	72.9	65.4	55.6	47.4	64.0	+1.6
.....	44.6	53.6	57.0	61.3	62.5	78.7	81.6	83.4	77.2	64.0	51.0	44.6	63.3	+ .9
.....	44.5	46.5	49.7	55.8	64.1	73.9	83.4	77.4	74.7	65.3	50.0	49.4	61.2	−1.2
.....	50.0	53.0	55.6	63.6	69.3	72.8	78.7	76.4	71.5	57.5	51.0	45.9	62.1	− .3
.....	44.1	44.4	52.5	56.6	67.4	75.6	84.3	81.2	60.3	58.3	51.3	47.5	60.2	−2.2
.....	41.2	45.1	58.3	56.3	64.3	80.3	84.9	79.9	75.4	57.7	50.6	44.4	61.5	− .9
.....	46.2	45.9	51.6	56.8	68.0	69.6	78.4	81.5	67.3	62.1	54.7	47.5	60.8	−1.6
.....	47.5	53.5	61.0	62.1	70.4	71.6	80.7	83.8	74.8	65.6	52.7	49.3	64.4	+2.0
.....	46.2	54.5	52.8	57.7	66.9	79.1	82.6	81.5	75.6	60.7	51.3	50.0	63.2	+ .8
.....	48.7	43.4	58.9	60.2	68.8	77.1	85.9	81.3	76.4	71.1	55.2	48.2	64.4	+2.0
.....	40.9	53.9	54.5	67.0	68.1	70.7	80.9	83.7	81.2	68.2	54.8	48.3	64.5	+2.1
.....	45.8	51.6	56.8	61.0	66.8	80.0	81.3	80.0	76.0	61.4	54.4	44.8	63.3	+ .9
.....	39.2	45.2	50.8	60.3	67.6	72.6	80.4	79.5	74.4	65.0	57.9	45.0	61.5	− .9
.....	48.5	44.4	55.0	57.8	66.3	72.2	82.6	83.1	72.9	66.0	56.8	42.5	62.4	0.
.....	47.1	53.0	56.0	54.1	65.6	71.8	78.7	80.4	72.0	63.5	56.1	47.6	62.2	− .2
.....	43.2	46.8	49.8	54.6	65.8	73.4	80.4	81.0	67.5	61.4	53.5	50.2	60.6	−1.8
.....	42.4	45.3	51.5	61.4	66.8	69.1	83.0	82.0	74.8	63.9	59.0	45.0	62.0	− 4
.....	43.8	52.8	52.8	59.1	66.2	78.2	80.0	81.2	68.5	67.0	53.6	43.4	62.2	− .2
.....	48.8	53.2	53.8	52.2	61.0	77.4	85.3	78.8	72.8	67.2	50.8	49.0	62.5	+ .1
.....	45.8	47.0	54.4	63.2	72.6	74.0	82.1	80.2	72.6	62.9	49.7	46.0	62.0	− .4
.....	42.4	51.0	59.2	64.4	63.6	75.4	83.1	81.3	72.6	64.3	53.6	45.7	62.5	+ .1
.....	48.8	51.6	52.2	60.8	63.2	77.9	82.0	73.8	78.0	61.0	54.4	45.5	62.4	0.
ns (22 ears) .	45.2	49.3	54.6	59.3	66.6	75.0	81.9	81.1	72.9	63.7	53.5	46.7	62.4	

Temperature summaries, Red Bluff, Cal.

th.	Highest monthly mean.		Lowest monthly mean.		Absolute maximum.			Absolute minimum.			Mean daily range.	Mean daily variability of mean temperature.	Mean relative humidity.	
	Year.	° F.	Year.	° F.	Day.	Year.	° F.	Day.	Year.	° F.			5 a.m.	5 p.m.
													P. ct.	*P. ct.*
y....	1881	50.0	1890	39.2	27	1899	77	14	1888	18	15.6	3.6	87	68
ry...	1886	54.5	1887	43.4	25	1888	82	14	1884	22	18.9	3.1	82	56
.....	1885	61.0	1880	49.7	9	1892	86	16	1880	28	19.2	3.0	82	53
.....	1888	67.0	1892	54.1	24	1898	96	18	1885	34	22.2	3.3	76	43
.....	1897	72.6	1896	61.0	29	1887	110	11	1892	38	24.1	3.9	71	38
.....	1878	81.0	1884	69.6	30	1891	110	1	1898	44	27.1	3.5	59	26
.....	1887	85.9	1884	78.4	8	1887	112	1	1881	53	30.5	3.2	49	18
.....	1885	83.8	1889	73.8	22	1891	114	22	1881	52	30.6	3.0	49	20
ber .	1888	81.2	1882	60.3	1	1891	107	9	1884	46	26.7	3.2	57	28
r	1887	71.1	1881	57.5	5	1892	97	14	1881	32	24.6	3.3	67	38
ber .	1894	59.0	1897	49.7	3	1890	88	30	1880	26	21.4	3.5	75	55
ber .	1893	50.2	1891	42.5	5	1885	79	13	1884	25	13.4	3.5	87	70
.....	.....	85.9	.....	39.2	.....	.....	114	.....	.....	18	22.8	3.3	70	43

Precipitation exceeding 2.50 inches in any consecutive twenty-four hours.

	Inches.
January 16, 1878	5.11
December 5, 1879	5.04
January 29, 1881	3.35
December 14, 1881	2.60
November 3, 1882	2.88
November 10, 1885	4.73
December 15, 1896	2.64
January 10, 1899	4.04

Monthly and annual precipitation, in inches, at Red Bluff, Cal., with annual departures from normal.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Departure from normal.
1878	20.71	16.66	4.16	2.26	0.89	0	0	0	0.42	1.56	1.66	0.69	49.01	+23.6
1879	3.18	3.67	5.39	2.12	2.18	.30	.04	.28	T.	.48	6.05	9.95	33.64	+ 8.0
1880	2.01	1.66	1.70	7.05	1.04	0	0	0	0	.08	.14	12.85	26.53	+ .5
1881	9.40	2.79	.51	1.83	.79	.51	T.	0	1.07	1.61	.73	5.69	24.93	- .3
1882	2.81	3.94	2.67	2.12	.33	.15	0	0	.49	2.80	5.07	1.44	21.82	- 3.0
1883	.87	.39	2.60	1.96	2.96	T.	0	T.	1.04	2.68	.74	.52	13.76	-11.6
1884	3.55	2.21	7.81	4.31	.18	.97	0	T.	.36	.90	.04	7.73	28.06	+ 2.6
1885	1.84	1.19	T.	.62	.64	1.37	.05	0	2.91	.10	17.05	3.86	29.63	+ 4.3
1886	4.85	.18	1.31	4.12	.73	T.	T.	T.	0	1.76	.34	3.92	17.21	- 8.1
1887	.57	5.21	1.13	1.76	.77	.26	T.	T.	.06	0	1.52	2.32	13.60	-11.7
1888	4.08	2.17	3.47	.53	.51	2.61	.07	0	.33	T.	4.32	6.85	24.94	- .6
1889	.51	.71	6.83	1.11	2.04	.64	0	0	0	8.41	3.37	9.25	32.87	+ 7.4
1890	6.55	3.67	6.14	1.70	2.67	.11	0	0	1.55	.01	0	3.20	25.60	+ .2
1891	1.36	10.68	1.42	2.27	1.50	.55	.17	0	.19	.64	.46	3.80	23.04	- 2.5
1892	4.30	3.11	2.69	2.92	3.02	.27	T.	T.	.29	1.42	7.25	8.21	33.48	+ 8.0
1893	3.82	3.22	6.08	1.42	.61	0	.03	0	1.23	1.09	4.22	2.64	24.36	- 1.0
1894	5.29	2.30	2.40	.55	1.46	1.00	.02	T.	1.11	.89	.95	11.01	26.98	+ .9
1895	8.29	2.86	2.59	.34	1.65	0	.16	0	1.76	T.	1.93	2.99	22.57	- 2.8
1896	7.30	.27	3.06	3.67	2.42	T.	0	.54	.63	.66	3.41	6.20	28.46	+ 3.0
1897	3.22	6.26	1.99	1.22	.06	1.25	0	T.	.03	2.70	1.49	1.86	20.08	- 5.3
1898	.59	5.45	.01	.63	2.28	.14	0	T.	.45	.46	1.21	1.69	12.91	-12.8
1899	9.29	.01	6.22	.72	.69	.94	0	.02	0	3.02	4.08	3.08	28.07	+ 2.5
Average (22 yrs.)	4.74	3.57	3.19	2.06	1.34	.50	.02	.04	.63	1.30	2.95	5.40	25.56	

Greatest amount of precipitation, in inches, in twenty-four hours.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	The year.
8	5.11	2.41	0.96	0.76	0.40	0	0	0	0.22	1.38	1.20	0.45	5.11
9	1.54	1.36	1.55	.43	.58	.30	.03	.28	0	.23	1.68	5.04	5.04
0	.94	.41	.78	2.03	.50	0	0	0	0	.08	.10	1.84	2.03
1	3.25	.45	.27	.56	.70	.44	0	0	.74	.68	.33	2.89	3.25
2	.91	1.38	.99	1.03	.26	.13	0	0	.37	1.05	2.88	.62	2.88
3	.76	.39	1.14	1.72	1.10	0	0	0	1.04	1.03	.43	.40	1.72
4	1.12	1.06	2.17	1.47	.14	.56	0	T.	.17	.68	.04	2.00	2.17
5	.63	.45	T.	.22	.58	.71	.05	0	2.91	.06	4.73	1.83	4.73
6	1.89	.18	.43	1.01	.22	T.	T.	T.	0	1.35	.21	1.81	1.89
7	.30	1.59	.62	.82	.39	.14	T.	T.	.06	0	.77	.83	1.59
8	.66	.96	1.25	.53	.15	.84	.04	T.	.33	T.	1.61	1.43	1.61
9	.16	.45	1.95	.31	.85	.58	0	0	0	1.70	1.70	1.83	1.95
0	2.02	1.16	1.71	1.51	1.67	.06	0	0	1.40	.01	0	1.48	2.02
1	.92	3.80	.56	.82	.48	.32	.16	0	.10	.44	.19	.81	3.80
2	1.44	1.36	.91	1.12	1.56	.22	T.	T.	.29	.72	2.30	1.79	2.30
3	1.89	1.40	1.20	.65	.26	0	.03	0	.81	.96	1.85	.85	1.89
4	2.00	.86	.85	.41	.55	.45	.02	T.	1.11	.38	.91	1.70	2.00
5	2.36	1.70	1.05	.16	1.06	T.	.10	T.	.96	T.	.75	1.26	2.36
6	1.38	.17	.58	1.80	.77	T.	0	.54	.58	.61	1.36	2.64	2.64
7	1.04	1.12	.90	.83	.04	.70	0	T.	.02	1.08	1.00	.93	1.04
8	.25	1.54	.01	.41	1.09	.12	0	T.	.20	.23	.58	.92	1.54
9	4.04	.01	1.56	.48	.34	.79	0	.02	0	1.02	1.00	1.54	4.04
Greatest monthly	5.11	3.80	2.17	2.03	1.67	.84	.10	.54	2.91	1.70	4.73	5.04	

Summary of weather conditions at Red Bluff, Cal.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
verage number of—													
Clear days	11	12	13	13	17	23	28	28	24	21	17	11	218
Partly cloudy days	10	9	10	11	9	6	3	2	5	7	7	9	88
Cloudy days	10	7	8	6	5	1	0	1	1	3	6	11	59
Rainy days	11	9	11	8	6	4	1	0	3	4	6	12	75
Mean cloudiness	5	4.4	4.6	4.1	3.5	2.1	0.5	0.9	1.7	2.6	4	5.5	3.3

Number of thunderstorms, Red Bluff, Cal.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1884	----	----	----	----	2	----	1	1	2	1	----	----	7
1885	----	1	----	1	1	1	2	----	1	----	----	----	7
1886	----	1	----	----	1	----	----	----	----	1	----	----	3
1887	----	----	----	1	1	----	1	----	----	----	----	2	5
1888	1	----	----	----	2	2	----	1	4	----	----	----	10
1889	----	----	2	1	2	----	----	----	----	----	----	----	5
1890	----	----	----	----	1	2	----	1	----	----	----	----	4
1891	----	----	1	----	1	----	----	----	----	----	----	----	2
1892	----	----	1	1	----	2	1	----	----	----	1	1	7
1893	----	----	----	1	----	----	1	----	1	----	----	----	3
1894	----	----	----	----	2	1	----	----	----	----	----	----	3
1895	----	1	1	----	----	----	----	----	----	----	----	----	2
1896	----	----	2	1	2	----	----	----	----	----	----	----	5
1897	----	----	----	----	----	2	----	----	----	1	----	----	3
1898	----	2	----	----	1	2	----	----	1	----	----	----	6
1899	----	----	1	----	----	----	----	----	----	1	----	----	2
1900	----	2	1	----	----	1	----	1	1	----	----	----	----

Dates of first and last killing frosts from 1882 to 1899, inclusive.

Year.	Last in spring.	First in autumn.	Year.	Last in spring.	First in autumn.
1882	Mar. 20	Nov. 12	1891	Feb. 25	Dec. 5
1883	Feb. 17	Nov. 25	1892	Feb. 9	Nov. 24
1884	Mar. 11	Dec. 11	1893	Mar. 13	Nov. 19
1885	Feb. 9	Dec. 21	1894	Mar. 4	Nov. 23
1886	Mar. 1	Nov. 21	1895	Mar. 14	Nov. 25
1887	Feb. 27	Nov. 24	1896	Apr. 19	Nov. 28
1888	Mar. 3	Dec. 6	1897	Mar. 30	Nov. 7
1889	Feb. 17	Dec. 27	1898	Mar. 24	Nov. 30
1890	Feb. 27	Dec. 10	1899	Feb. 7	Dec. 19

RUN-OFF.

A gaging station was established January 30, 1901, on Stony Creek at Julian's ranch, 6 miles northwest of Fruto and 1¾ miles above the proposed Mill Site dam. Daily gage heights have been kept and numerous meter measurements have been made, from which rating curves have been constructed for estimating the daily flow and total annual run-off from the basin. The total run-off from February 1 to

31, 1901, was estimated as 298,578 acre-feet or 0.57 second-
uare mile, which amounts to 7.39 inches in depth over the
ershed when taken as 760 square miles.

daily flow from February 1, 1901, to December 31, 1902,
n page 35; also the estimated monthly discharge for 1901

discharge in second-feet of Stony Creek at Julian's ranch for 1901.

[Drainage area, 760 square miles.]

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	1,225	2,215	435	555	195	2	10	5	300	47	340
.....	1,125	1,785	435	555	195	2	10	5	260	35	1,325
.....	1,025	1,540	490	490	165	2	10	5	260	35	630
.....	1,025	1,325	490	490	165	2	10	5	225	35	3,875
.....	1,225	1,225	435	490	165	.....	5	5	225	35	1,325
.....	1,025	1,125	490	435	140	.....	5	5	225	35	1,125
.....	925	1,025	435	385	140	.....	5	5	195	35	435
.....	925	925	435	385	117	.....	5	5	165	35	435
.....	825	925	385	385	97	.....	5	5	140	35	385
.....	825	1,025	340	340	97	.....	5	5	140	47	340
.....	725	1,125	340	340	77	.....	5	5	117	47	340
.....	725	1,025	300	340	62	.....	5	5	97	47	260
.....	1,125	925	300	340	62	.....	5	5	77	47	225
.....	1,920	825	340	340	47	15	5	5	77	47	195
.....	1,325	825	385	340	47	15	5	10	62	77	165
.....	3,875	825	385	300	35	15	5	10	47	97	165
.....	2,790	825	340	300	35	15	5	10	35	62	140
.....	2,215	825	340	300	25	15	2	10	25	77	140
.....	10,385	725	300	260	25	15	2	10	15	77	140
.....	8,215	630	300	260	15	15	2	10	15	165	117
.....	5,611	630	300	300	15	15	2	10	10	165	117
.....	3,875	630	260	300	15	10	2	15	5	340	97
.....	6,479	555	260	300	10	10	2	15	5	340	77
.....	4,526	555	225	300	10	10	2	15	2	300	77
.....	3,441	555	225	340	10	10	2	25	.....	225	97
.....	3,224	555	225	300	5	10	2	25	.....	195	97
.....	2,790	555	225	300	5	10	2	25	260	195	117
.....	2,390	555	225	300	5	10	2	25	300	195	117
.....	.....	490	630	260	5	10	2	25	340	1,125	97
1,325	.....	490	555	260	5	10	2	725	340	630	97
1,325	.....	435	.....	225	.....	10	2	.....	62	.....	97

Daily discharge, in second-feet, of Stony Creek at Julian's ranch, for 1902.

[Drainage area, 760 square miles.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	D
1	125	109	5,860	920	690	370	9	2	5	55	109	1
2	150	125	7,000	1,000	620	320	9	2	5	55	109	1
3	125	125	4,360	1,080	550	270	9	2	5	55	109	1
4	125	109	3,750	1,165	550	270	9	2	5	55	109	1
5	125	125	2,900	1,250	490	270	9	2	5	55	109	2
6	109	430	3,315	2,510	490	225	5	2	5	55	125	1
7	109	2,390	3,315	4,680	840	225	2	2	5	55	125	1
8	109	3,175	5,170	3,315	1,000	225	2	2	5	67	490	1
9	109	3,175	4,520	2,900	920	185	2	2	5	67	5,005	1
10	109	3,750	3,175	2,510	840	185	2	2	9	67	3,605	1
11	109	5,170	2,900	2,275	765	150	2	2	9	67	2,160	1
12	109	3,175	2,510	1,940	840	150	2	2	9	67	1,525	1
13	109	2,510	2,510	1,430	840	150	2	2	9	67	1,430	1
14	109	2,765	2,510	1,525	840	125	2	2	9	80	1,340	1
15	109	4,360	2,510	1,525	690	125	2	2	9	80	1,340	1
16	109	3,175	2,510	1,430	620	109	2	2	9	80	1,340	1
17	109	3,035	2,390	1,340	620	94	2	2	9	80	1,430	1
18	109	2,160	2,275	1,250	620	94	2	2	9	80	2,765	1
19	109	2,160	2,050	1,165	550	80	2	2	9	80	3,605	
20	109	2,390	2,050	1,080	490	67	2	2	9	80	2,635	
21	109	3,315	1,940	1,165	490	55	2	2	9	80	2,160	
22	125	4,360	1,940	1,000	430	44	2	2	9	94	2,050	
23	125	7,600	1,080	1,080	430	44	2	2	9	94	1,940	
24	125	14,650	1,080	1,000	370	35	2	2	14	185	1,940	
25	109	13,150	1,000	1,080	370	35	2	2	14	225	1,835	
26	109	9,890	1,000	920	370	27	2	5	14	185	1,835	1
27	109	12,660	920	840	320	5	2	5	14	150	1,730	1
28	109	7,600	920	840	320	5	2	5	14	125	1,625	1
29	109	.....	920	765	270	5	2	5	14	125	1,525	1
30	109	.....	920	690	320	5	2	5	14	125	1,430	1
31	109	.....	920	.....	370	.....	2	5	.....	109	.....	1
Total	3,532	117,638	80,220	45,670	17,925	3,949	100	80	269	2,844	47,535	3
Mean	114	4,201	2,588	1,522	578	132	3	3	9	92	1,584	1
Run-off, per square mile	.15	5.53	3.41	2.00	.76	.17	0	0	.01	.12	2.08	
Run-off, in inches	.17	5.76	3.93	2.23	.88	.19	0	0	.01	.14	2.32	

Estimated monthly discharge of Stony Creek at Julian's ranch.

[Drainage area, 760 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.						
bruary [a]	10,385	725	2,707	150,339	3.56	3.71
ırch	2,215	435	893	54,908	1.18	1.36
ıril	630	225	361	21,481	.48	.54
ıy	555	225	349	21,459	.46	.53
ne	195	5	66	3,927	.09	.10
ly	10	0	7	430	.01	.01
ıgust	10	2	4	246	.01	.01
ptember	725	5	35	2,083	.05	.06
tober	340	0	130	7,993	.17	.20
ovember	1,125	35	161	9,580	.21	.23
ecember	3,875	77	425	26,132	.56	.64
11 months	10,385	0	428	298,578	.57	7.39
1902.						
nuary	150	109	114	7,010	.15	.17
ebruary	14,650	109	4,201	233,312	5.53	5.76
arch	7,000	920	2,588	159,130	3.41	3.93
ıril	4,680	690	1,522	90,565	2.00	2.23
ıy	1,000	270	578	35,540	.76	.88
ne	370	5	132	7,855	.17	.19
ly	9	2	3	184	0	0
ıgust	5	2	3	184	0	0
ptember	14	5	9	536	.01	.01
tober	225	55	92	5,657	.12	.14
ovember	5,005	109	1,584	94,255	2.08	2.32
cember	2,765	690	1,132	69,604	1.49	1.72
The year	14,650	2	997	703,832	1.31	17.35

Maximum flood discharge of Stony Creek February 19, 1901, 8 p. m., estimated, 18,000 second-

SILT.

The vegetable covering, geologic character, and grades of the water-ed of Stony Creek and tributaries are such that the streams, even flood, carry a comparatively small quantity of silt.

The setting aside of the principal part of the watershed as a forest ·erve would assure the preservation of the forest at the headwaters d *the regulation of the* run-off, and hence the continuation of the

present favorable condition for the long life of storage reservoirs that may be built to impound the flood waters of these streams.

STORAGE POSSIBILITIES.

For the investigation of the storage possibilities of Stony Creek nearly the entire drainage basin was visited. Stony Creek has a very peculiar topographic catchment area. The main stream, flowing northerly and parallel with the Coast Range, lies wholly in the sedimentary rock, and is fed by several tributaries coming into it from the west from the granitic crest of the range. These tributaries, until they enter the sedimentary rock, have a very heavy grade, and reservoir sites are therefore not found thereon. At various points in the basin a conglomerate of more or less hardness is upturned in lines parallel with the axis of the main range, and has resisted erosion to a very large extent. Wherever this ridge has been crosscut by the various streams, dam and reservoir sites of more or less merit are found.

No exploration for bed rock was made at any of the following dam sites, and consequently the estimates in this particular are merely preliminary and should be confirmed before construction is undertaken.

GRINDSTONE CREEK.

Grindstone Creek joins Stony Creek in sec. 15, T. 21 N., R. 6 W., Mount Diablo meridian, draining a large part of the most productive portion of the basin. At a point about 4 miles above its mouth the stream intersects and passes through one of the conglomerate ridges above referred to, but as its canyon above is narrow it was not considered of enough importance to make surveys to determine the reservoir capacity of this site.

SALT CREEK.

On Salt Creek the same conglomerate is upturned, and the reservoir conditions are practically the same, except that the water supply is much less.

NORTH FORK OF STONY CREEK.

On the North Fork of Stony Creek, at the town of Newville, a reservoir site was found and surveyed by means of a plane table up to the 60-foot contour. The capacity was found to be 25,400 acre-feet at that level, distributed over an area of 1,350 acres. The foundations and abutments for this dam are not good, however, and the land to be covered would be some of the most valuable in the county. The drainage area tributary to this reservoir site is insufficient to supply this amount of water except in years of excessive rainfall, therefore no estimates of cost of building a dam at this point were made. Owing to this insufficient drainage area, a reconnaissance by means of hand level and barometer was made to determine the possibility of diverting Thomas Creek, the next creek to the west, into this reservoir site. From the cursory examination made it appears that

are no engineering difficulties to be encountered which could overcome, except that of a heavy cost for the work. It would ly not be public policy, however, to divert this stream, as a oir site exists, and was surveyed by others several years ago, 3 miles south of the town of Paskenta, Tehama County, on s Creek. No information as to the capacity or cost of this oir could be obtained, and surveys were not considered justi- The dam site appears fair, and the basin above it is extensive. was outside of the Stony Creek investigation no surveys were The locality upon which this water should logically be diverted and naturally tributary thereto, either in the basin of Thomas or at the point where it debouches into the Sacramento Valley.

BRISCOE CREEK.

creek has a catchment area of 50 square miles of good moun- ainage. The crest of the drainage is a high mountain, locally

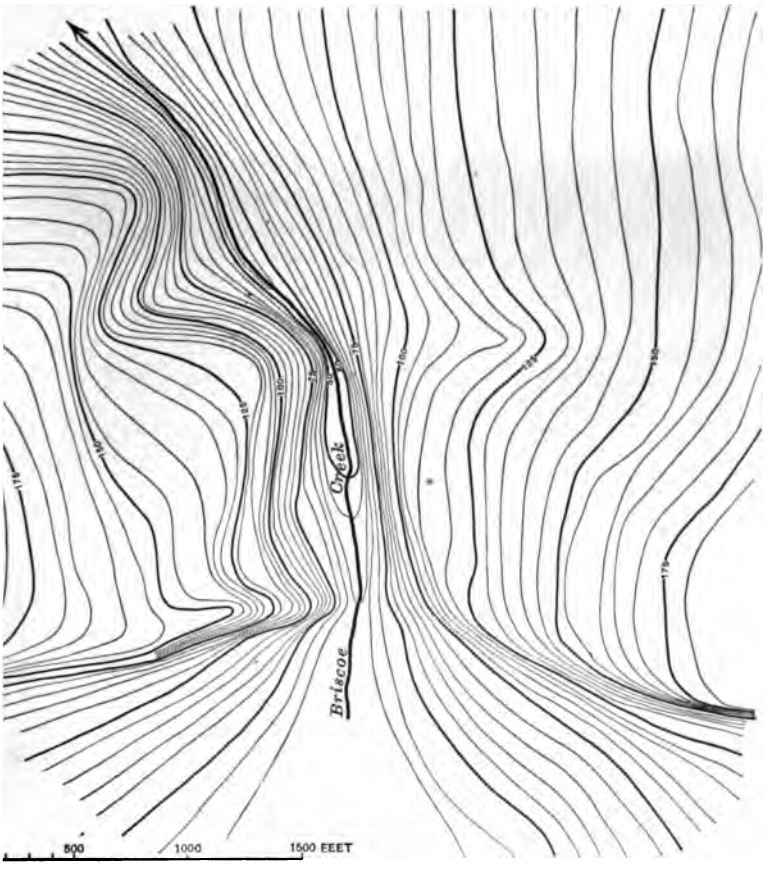


FIG. 2.—Briscoe dam site, Stony Creek.

as *Sheetiron Mountain*, and inhabitants of this locality report lies in what may be termed a "rainy belt," having a width of

about 6 miles and extending northeast from this mountain about 8 miles. Briscoe Creek, in sec. 30, T. 20 N., R. 6 W., M. D. M., intersects a conglomerate bed in a narrow rocky gorge that in places is only 3 feet

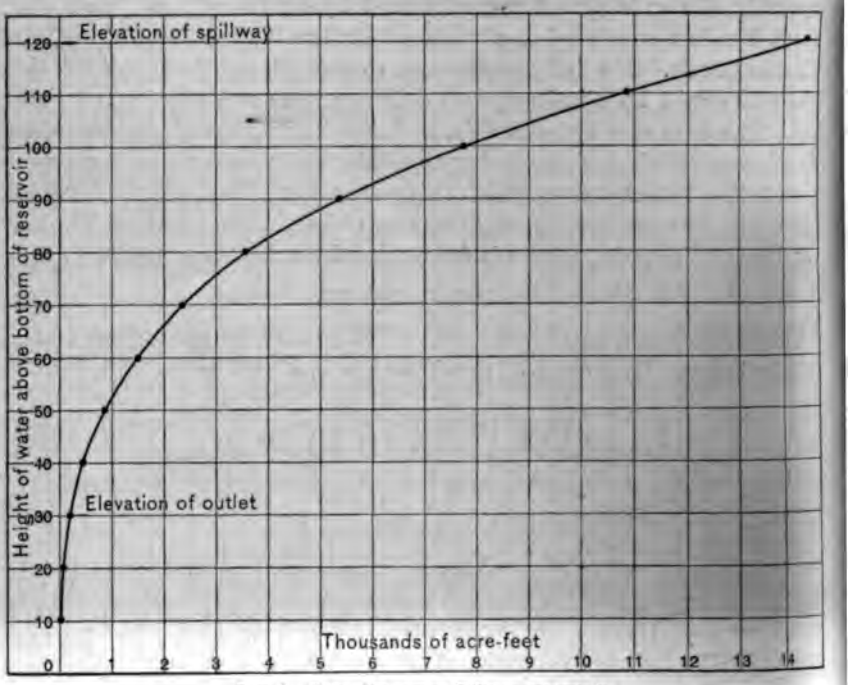


FIG. 3.—Capacity curve, Briscoe reservoir.

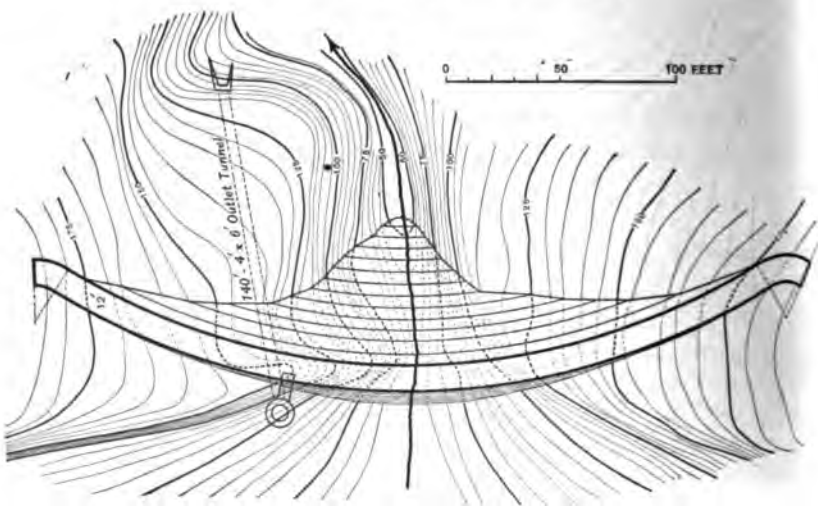


FIG. 4.—Plan of concrete dam, Briscoe reservoir.

wide. The site was surveyed and found to have a capacity of 14,385 acre-feet with a dam 125 feet high. A subsidiary dam at the divide, 1,700 feet north of dam site, will also be necessary, with a maximum

BRISCOE CREEK DAM SITE.

f 30 feet. The conglomerate at the dam site is very hard and , a sample taken weighing 143 pounds per cubic foot. Bed t the surface in the canyon at the dam site, and the walls of on are good.

onsidered that the best type of dam for this place will be a l concrete gravity dam with a concrete spillway at the sub-lam.

llowing estimates with regard to the concrete are based on mption that 25 per cent of the conglomerate rock will quarry

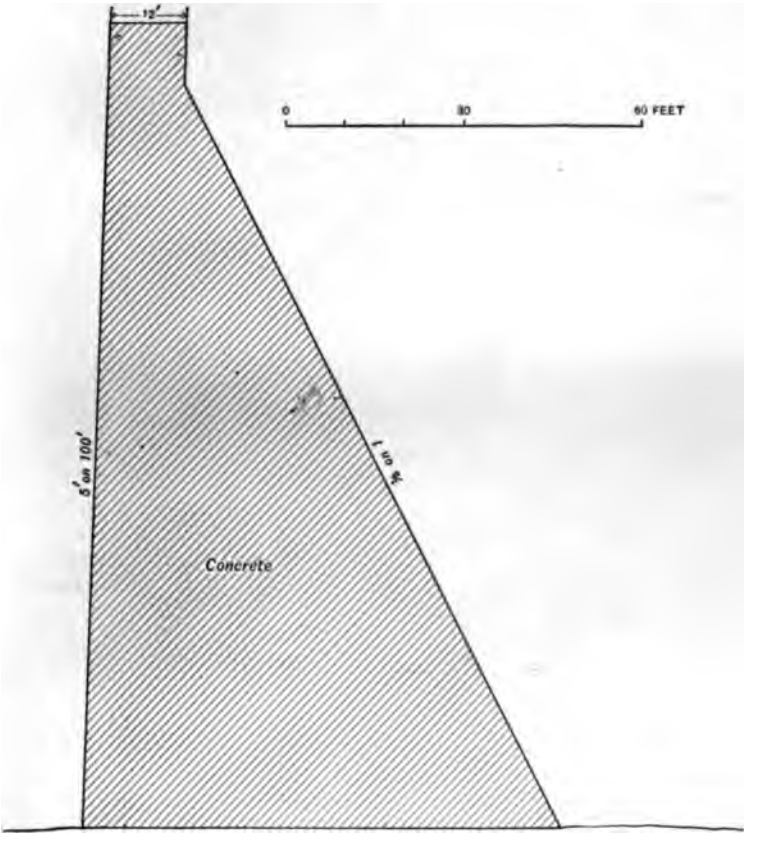


FIG. 5.—Section of concrete dam, Briscoe reservoir.

rge blocks and that these, after having their surfaces thor-leaned, can be embedded in concrete and will occupy at least of the cubic contents of the dam. For purposes of com-of cost, three types of dam have been estimated upon. First, e-mentioned concrete gravity dam of light cross section and curve upstream on a radius of 300 feet, with a small return each end, to fit the ground. With this design the overflow e through the spillway. Second, a concrete overflow dam *ith a 300-foot radius* and with a cross section the same as

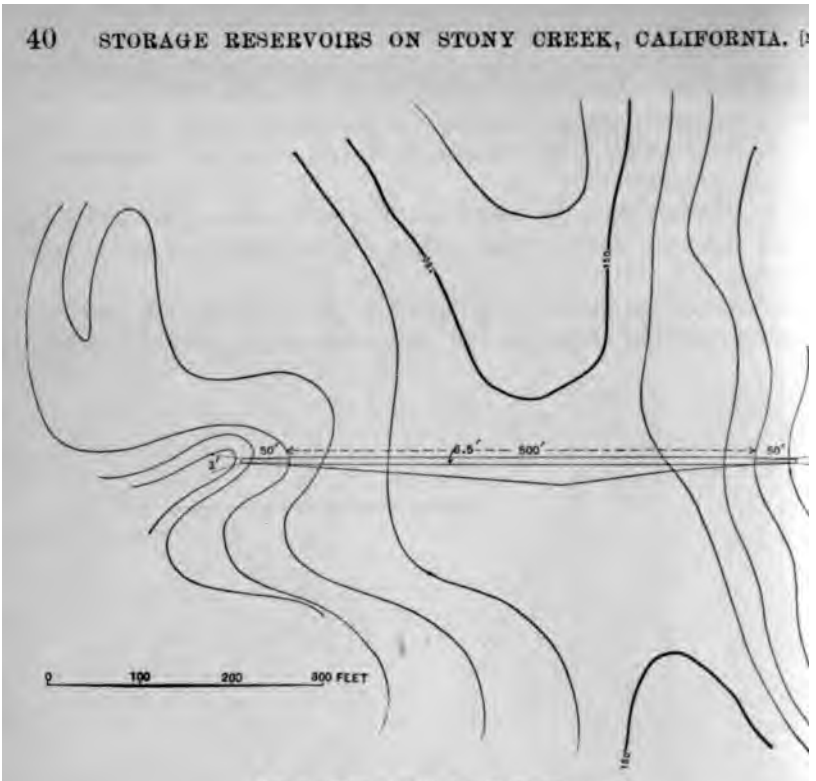


FIG. 6.—Plan of spillway, Briscoe reservoir.

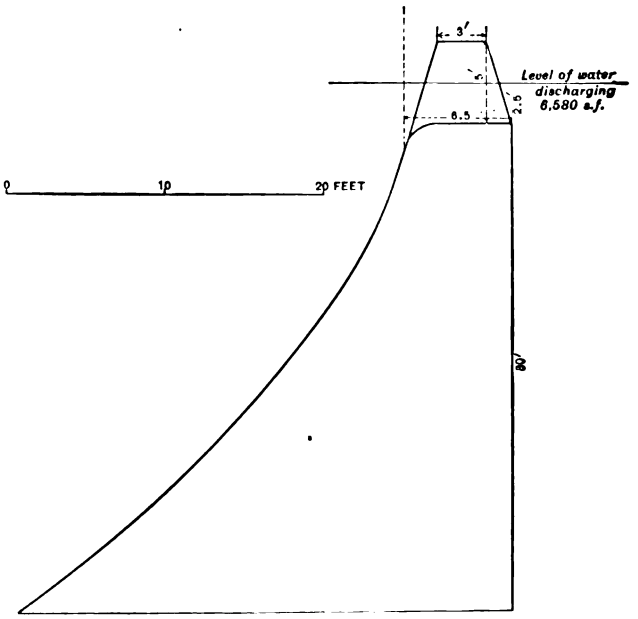
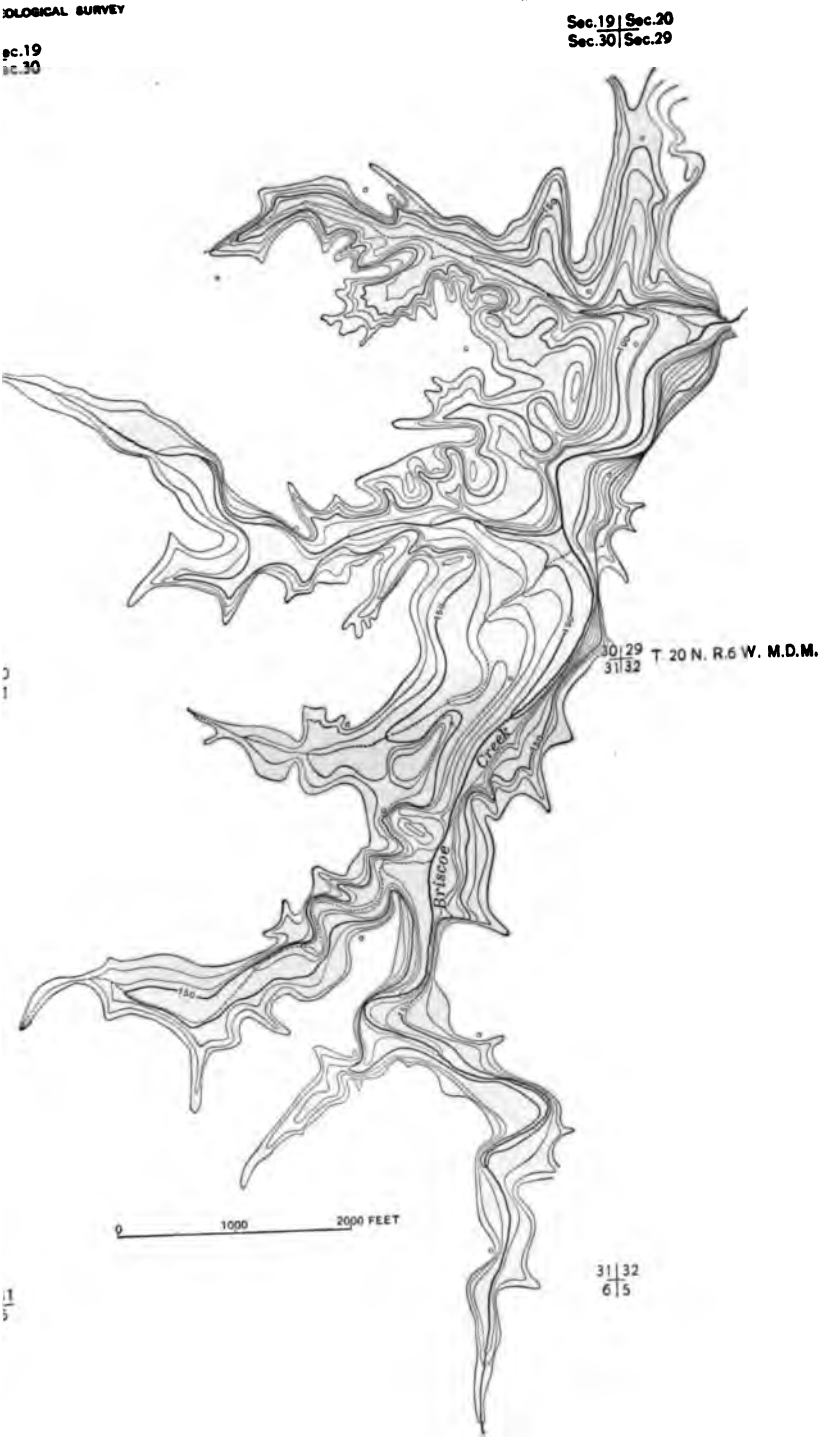


FIG. 7.—Section of spillway, Briscoe reservoir.



BRISCOE CREEK RESERVOIR SITE.

ed for the San Carlos dam on the Gila River, Arizona. In this he surplus water would pass over the dam. And third, a dry or loose rock dam with straight crest and a plank water face. onnection with the first and third type a concrete weir dam has lesigned for a spillway at the location for the subsidiary dam. the second type, or overflow dam, an earth subsidiary dam is ed with concrete cut-off wall riprapped on water face. A con- ower and tunnel outlet has been designed for each of the types; or the loose rock type requiring a longer outlet tunnel and bridge, connecting tower with crest of dam.

following data have been used in connection with designing an ow concrete dam for the spillway:

area of watershed is 50 square miles. Assuming the highest ble flood discharge at 100 second-feet per square mile, we have second-feet flood discharge. It is desirable to have the surface of the reservoir at the 180-foot contour (based upon an assumed), which, therefore, will be the level of lip of spillway weir. will give a depth of 120 feet of water in the reservoir. The point in the divide where the spillway is to be is at 154 feet ion. Maximum height to crest of weir, 26 feet; length on top -foot contour, 550 feet; length of weir opening at 180-foot con- 500 feet. With a depth of water over weir of 2½ feet the dis- capacity will be 6,580 second-feet, and with a depth over weir et the capacity will be 13,320 second-feet, and the water level within 1 foot of the crest of main dam, the latter case being a xtreme assumption.

Capacity of Briscoe reservoir.

Contour.	Height of dam.	Area.	Capacity between contours.	Total capacity.
Feet.	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*
70	10	1.7	8.5	8.5
80	20	10.7	62	70.5
90	30	17.2	139.5	210
100	40	30.6	239	449
110	50	53.0	418	867
120	60	71.9	624	1,491
130	70	99.1	855	2,344
140	80	144.8	1,219	3,565
150	90	211.1	1,779	5,344
160	100	271.0	2,410	7,754
170	110	347.8	3,094	10,848
180	120	401.5	3,747	14,595

tion of outlet 30 feet above bottom of reservoir.
tion of spillway 120 feet above bottom of reservoir.
ty, 14,595—210=14,385 acre-feet.

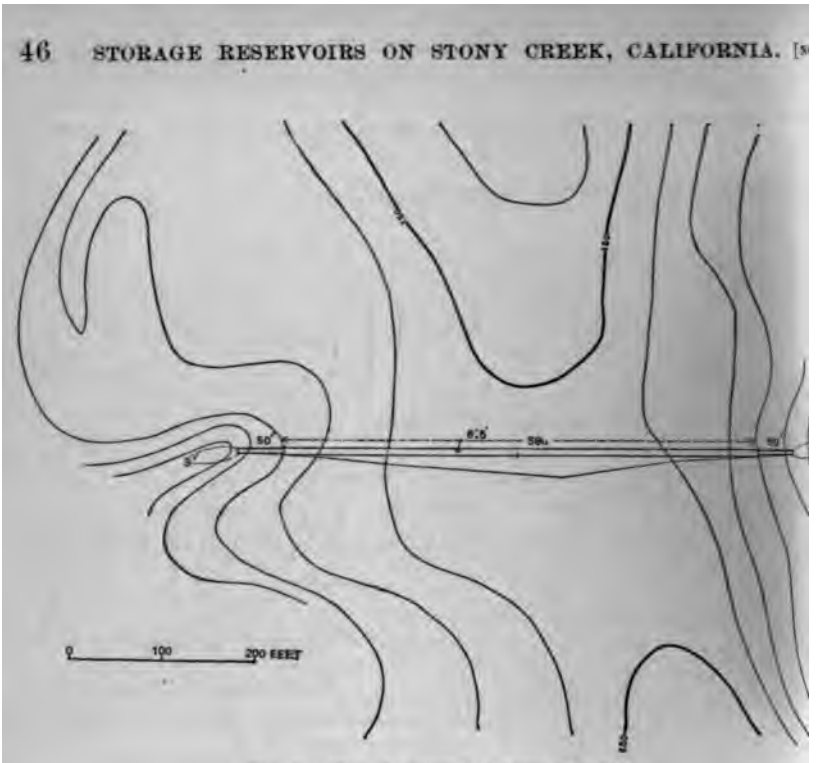


FIG. 15.—Plan of spillway, Briscoe dam site.

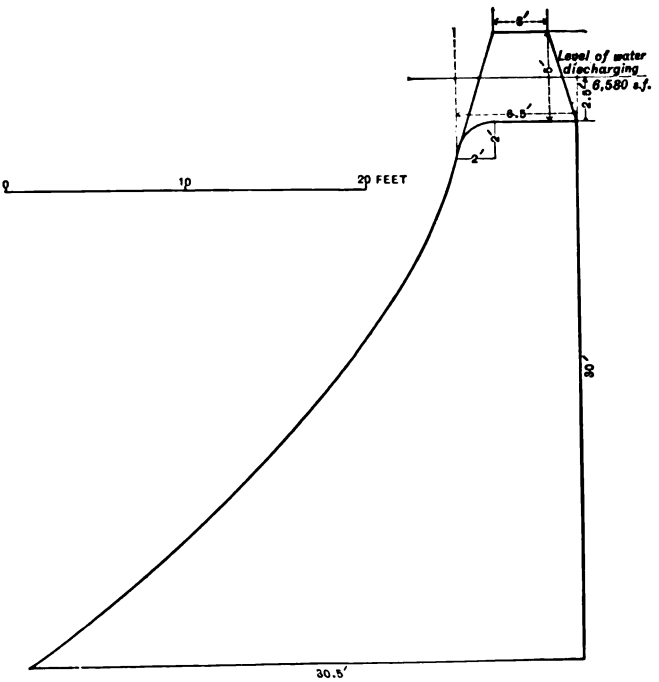


FIG. 16.—Section of spillway, Briscoe dam site.

BRISCOE CREEK DAM SITE ABUTMENT.

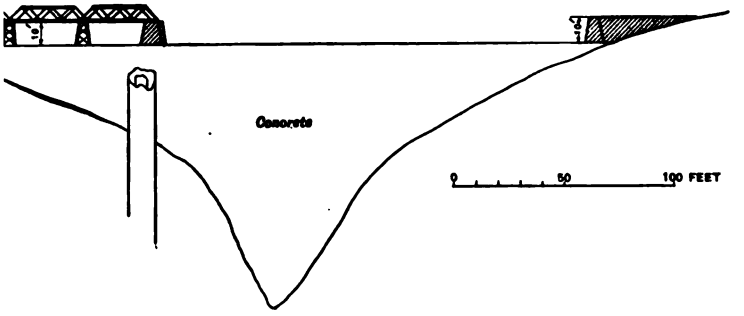


FIG. 9.—Elevation of concrete overflow dam, Briscoe reservoir.

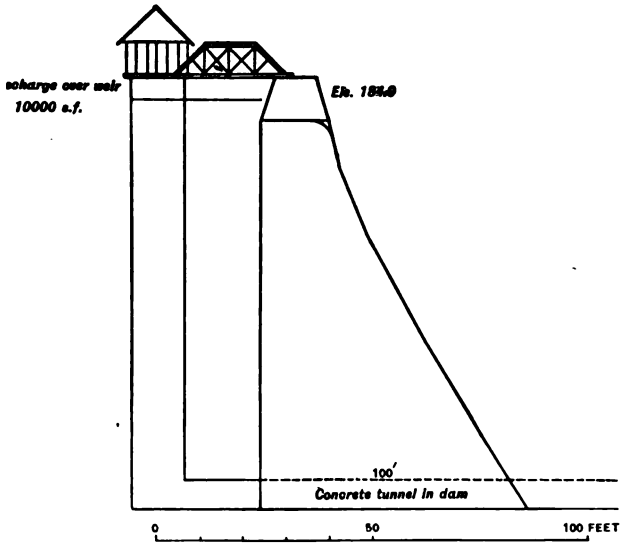


FIG. 10.—Cross section of concrete overflow dam, Briscoe reservoir.

26,000 acre-feet can be obtained from this reservoir. I obtain information as to the run-off available from this tributaries of Stony Creek the gaging station at Julian's established and is being maintained. Two types of dams designed for this location, corresponding to types Nos. Briscoe site.

Capacity of East Park reservoir.

Height of dam.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0	0	----------
10	2.28	11.4	11.4
20	44.19	232.5	243.9
25	----------	----------	654.3
30	119.97	820.8	1,064.7
40	254.86	1,874.1	2,938.8
50	478.14	3,665.0	6,603.8
60	640.49	5,593.2	12,197.0
70	1,100.36	8,704.3	20,901.3
75	1,240.67	5,852.6	26,753.9

Elevation of outlet, 25 feet.

Elevation of spillway, 75 feet.

Total capacity in acre-feet above outlet at 25-foot contour and contour, 26,753.9—654.3=26,099.6; 26,000 acre-feet was used as reservoir.

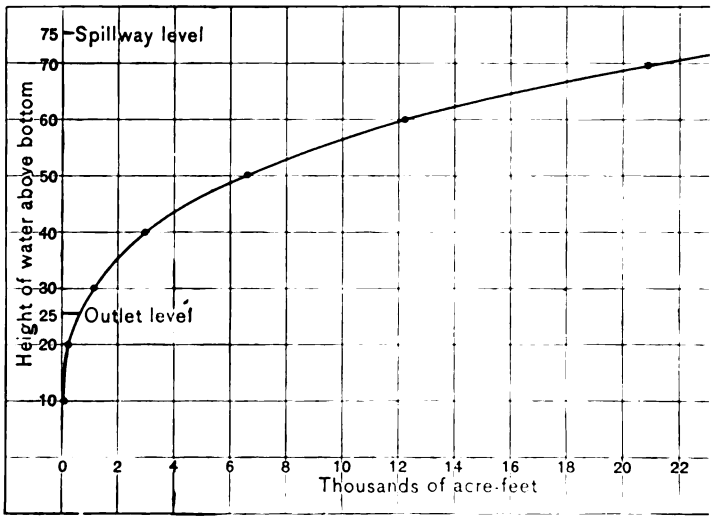
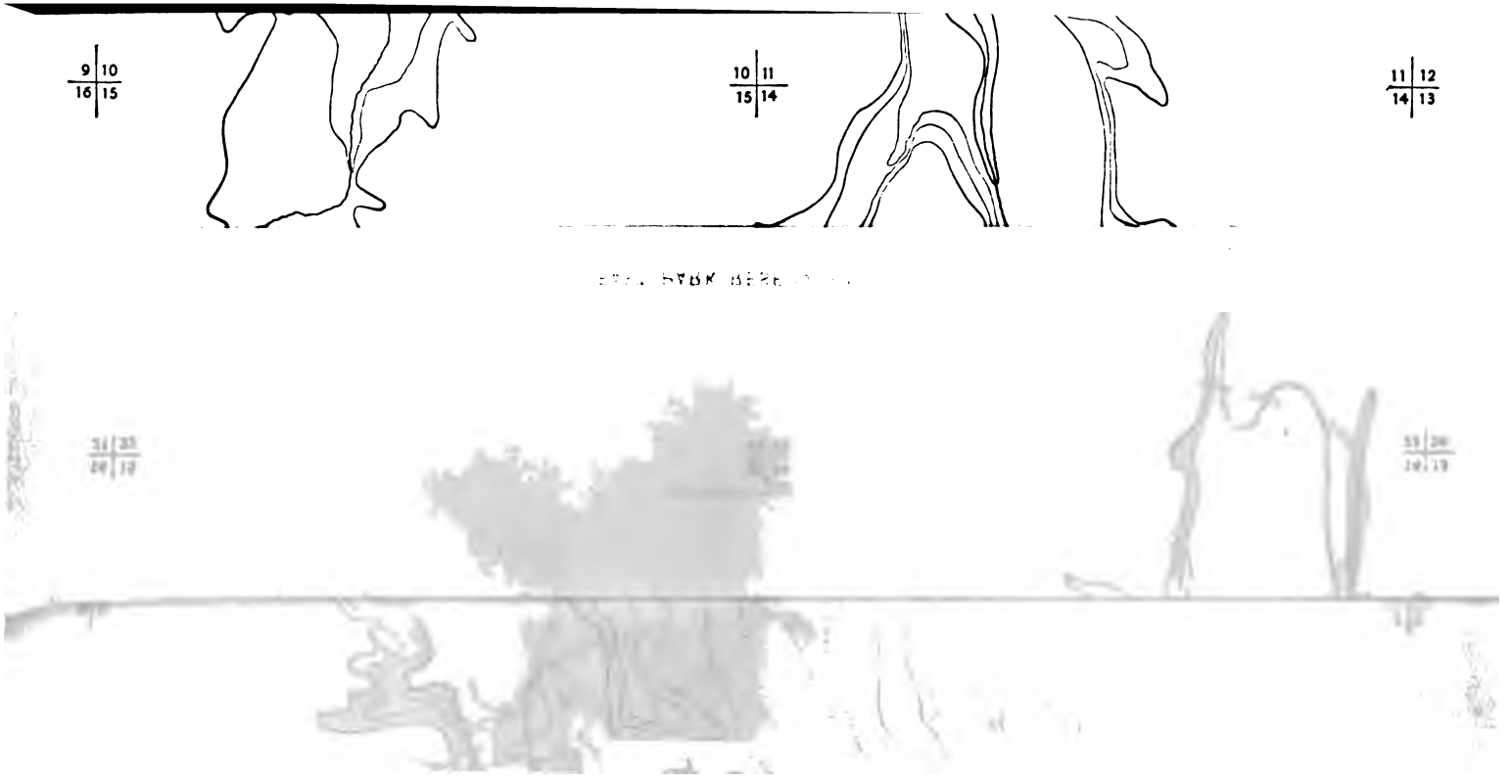


FIG. 17.—Capacity curve, East Park reservoir.


9 10
16 15
10 11
15 14
11 12
14 13

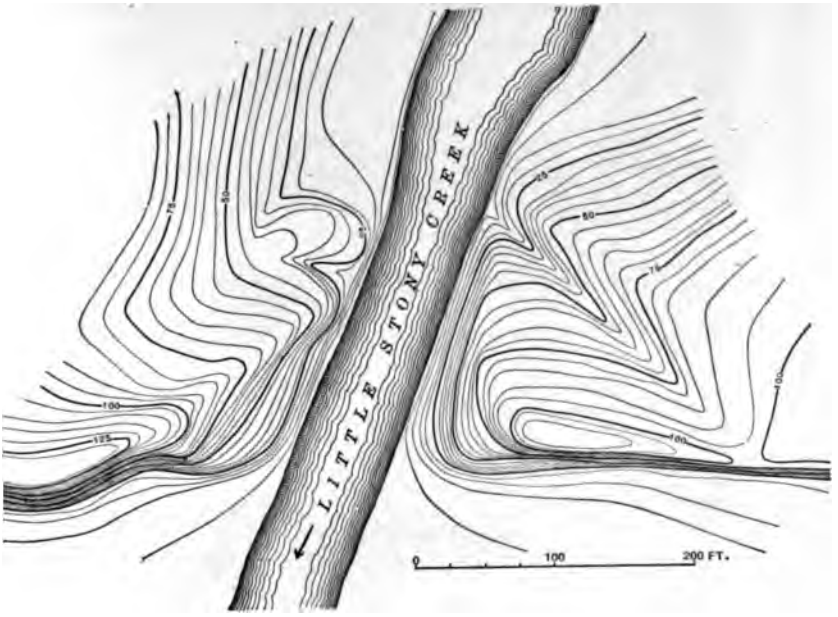


FIG. 18.—East Park dam site.

Estimate for dam on Little Stony Creek, type No. 1, concrete dam.

SPECIFICATIONS.

	Feet.
atter of water face	5 in 100
atter of lower face	1 in 2
levation of crest of dam	85
stimated elevation of base of dam	-30
laximum height of dam	115
levation of sill of spillway	75
levation of outlet	25

Capacity of reservoir, 26,000 acre-feet.

Capacity of spillway (water 2 feet below crest of dam), 15,070 cubic feet per econd.

COST.

3,900 cubic yards concrete, at $10	$139,000.00
xcavation to bed rock	6,000.00
pillway	3,285.00
utlet tunnel and works	7,876.00
ridge	720.00
able machinery	10,000.00
umber in flumes, etc., 10,000 feet B. M., at $20	200.00
ight of way	20,700.00
	187,781.00
ngineering and contingencies, 10 per cent	18,778.10
Total	206,559.10

Cost per acre-foot stored, $7.94.

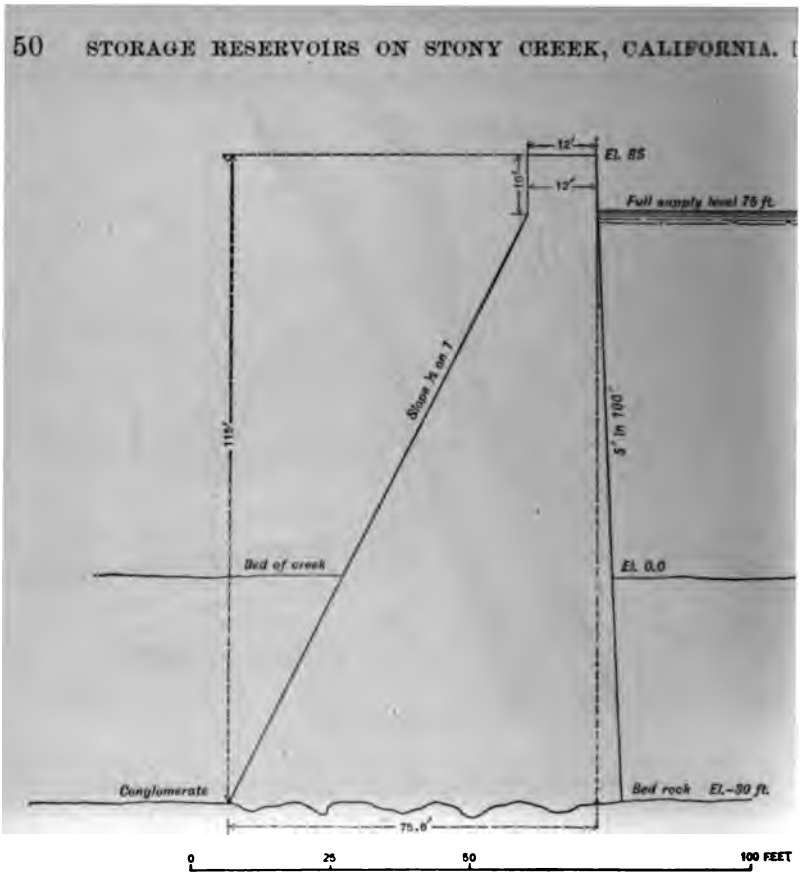


FIG. 19.—Maximum cross section of concrete dam, East Park dam site.

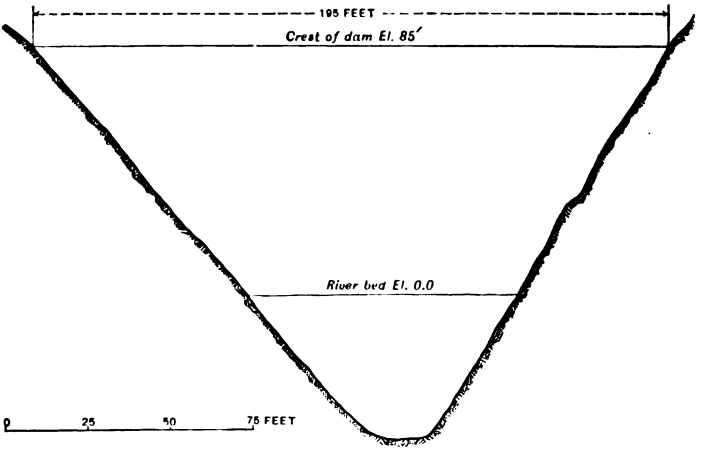


FIG. 20.—Profile of dam site, East Park dam site.

A. CONGLOMERATE AT EAST PARK.

B. MILL SITE DAM SITE ON STONY CREEK.

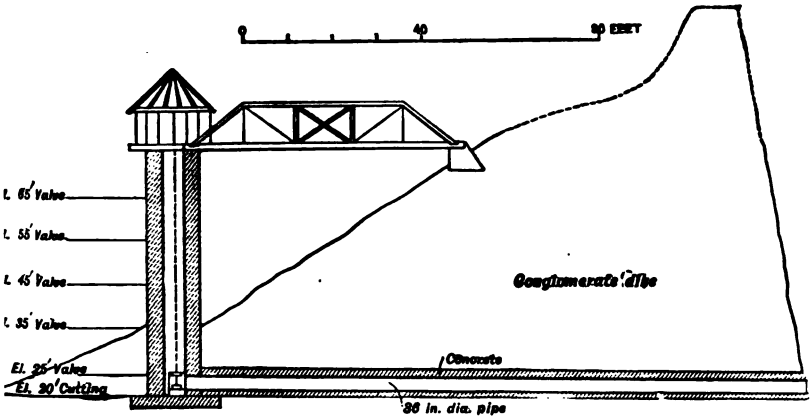


FIG. 21.—Outlet tunnel, East Park dam site.

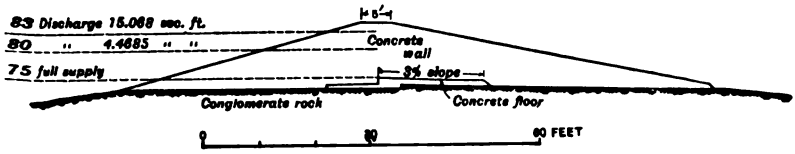


FIG. 22.—Profile of spillway, concrete dam, East Park dam site.

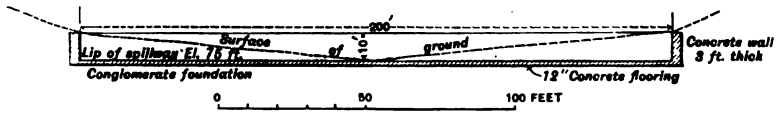


FIG. 23.—Cross section of spillway, concrete dam, East Park dam site.

Estimate of cost of rock-filled dam on Little Stony Creek. Type No. 2.

700 cubic yards, at $1.25	$65,875.00
avation to bed rock, 2,000 cubic yards, at $2	4,000.00
icrete to bed rock, 1,500 cubic yards, at $10	15,000.00
nk face, 170,000 feet B. M., at $25 a thousand	4,250.00
icrete between stringers under planks, etc., 481 cubic yards, at $10	4,810.00
icrete valve tower and bridge	7,040.00
nel and concrete filling	1,850.00
steway	18,250.00
rubble foundation under timber, 1,444 cubic yards, at $1.50 (extra st)	2,166.00
le machinery	10,000.00
ht of way	20,700.00
	153,941.00
ineering and contingencies, 10 per cent	15,394.00
Total	169,335.00

st per acre-foot stored, $6.51.

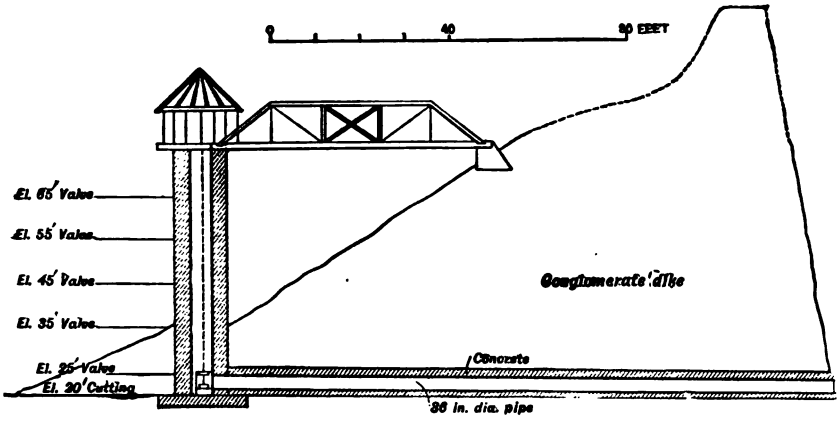


FIG. 21.—Outlet tunnel, East Park dam site.

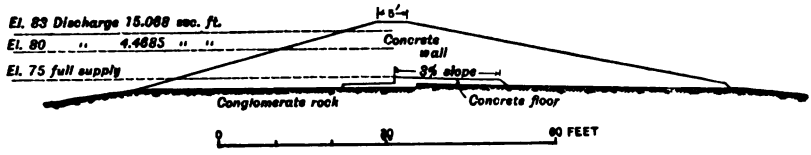


FIG. 22.—Profile of spillway, concrete dam, East Park dam site.

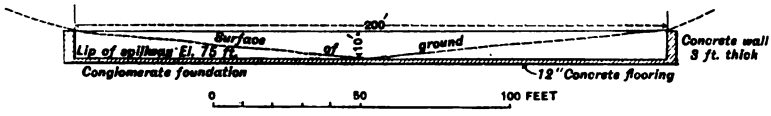


FIG. 23.—Cross section of spillway, concrete dam, East Park dam site.

Estimate of cost of rock-filled dam on Little Stony Creek. Type No. 2.

52,700 cubic yards, at $1.25	$65,875.00
Excavation to bed rock, 2,000 cubic yards, at $2	4,000.00
Concrete to bed rock, 1,500 cubic yards, at $10	15,000.00
Plank face, 170,000 feet B. M., at $25 a thousand	4,250.00
Concrete between stringers under planks, etc., 481 cubic yards, at $10	4,810.00
Concrete valve tower and bridge	7,040.00
Tunnel and concrete filling	1,850.00
Wasteway	18,250.00
Dry rubble foundation under timber, 1,444 cubic yards, at $1.50 (extra cost)	2,166.00
Cable machinery	10,000.00
Right of way	20,700.00
	153,941.00
Engineering and contingencies, 10 per cent	15,394.00
Total	169,335.00

Cost per acre-foot stored, $6.51.

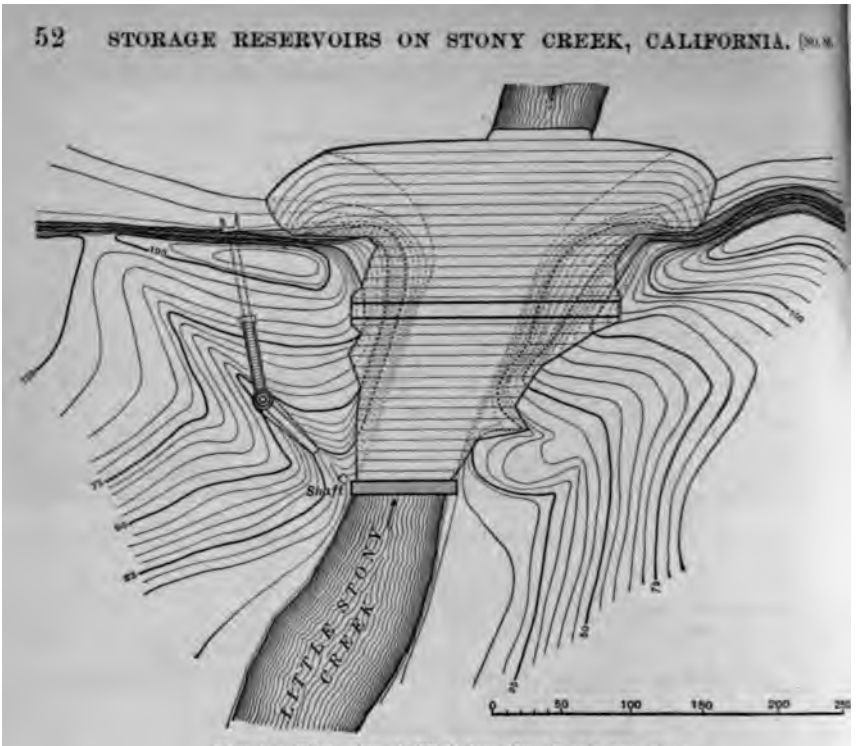


FIG. 24.—Plan of rock-filled dam, East Park dam site.

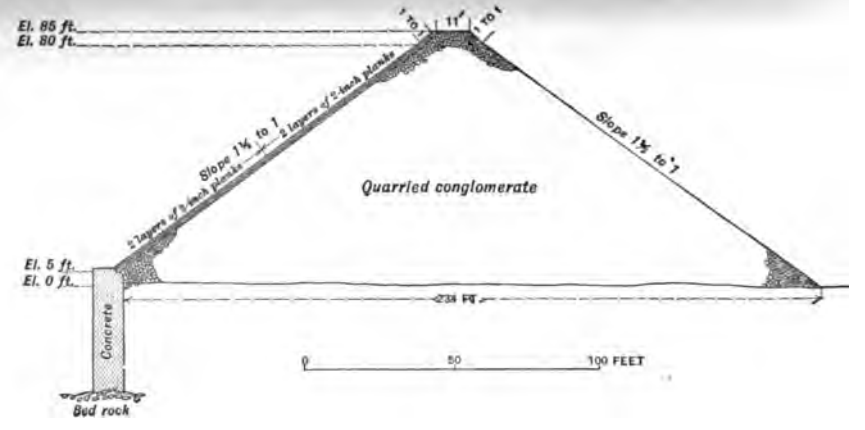
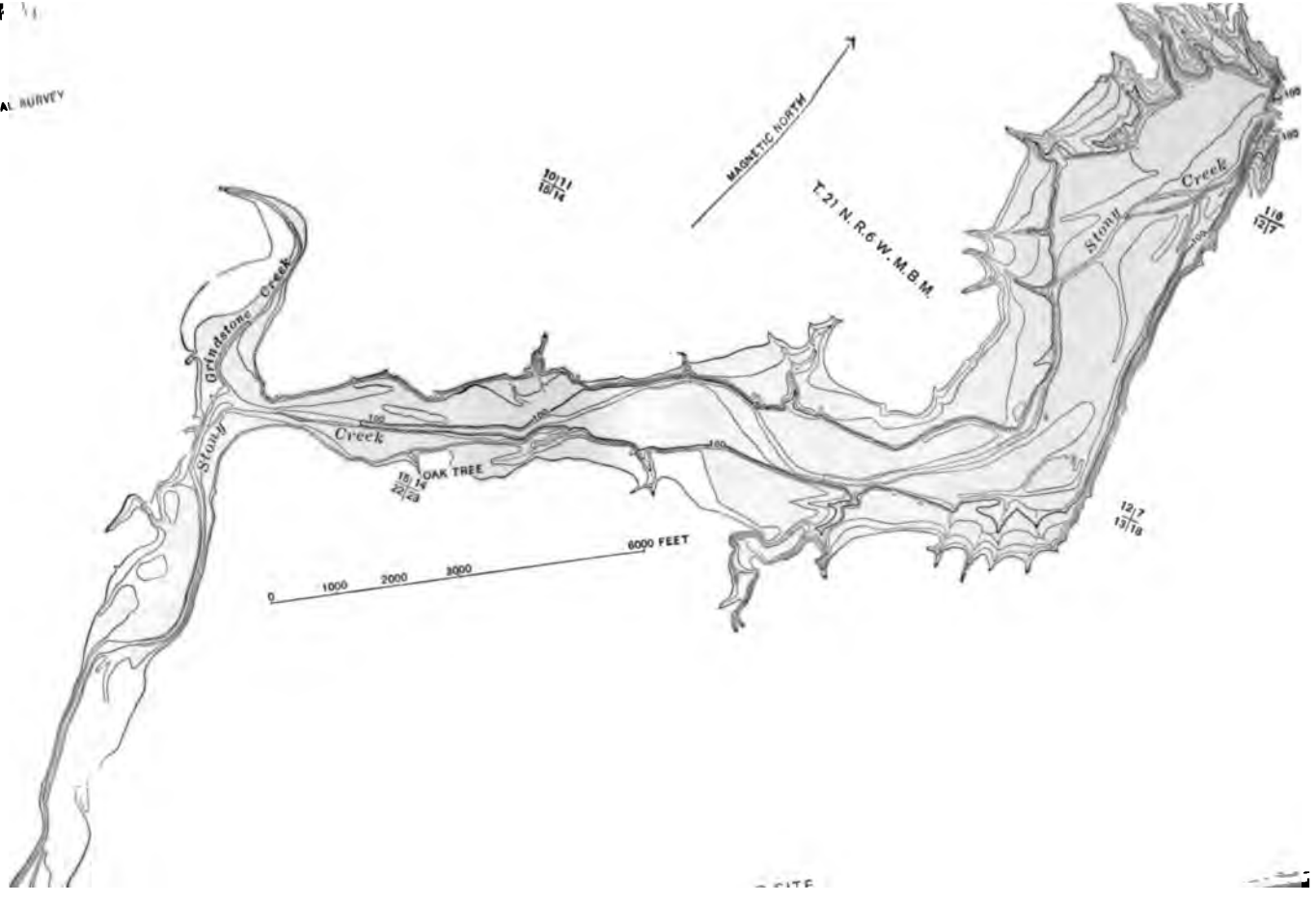


FIG. 25.—Maximum cross section of rock-filled dam, East Park dam site.

Type No. 1 is recommended for this location as being more sul stantial and serviceable than a rock-fill type.

There is a scarcity of sand at the dam sites on Little Stony Creel and the cost of concrete has been estimated upon the basis that the coı glomerate rock will have to be crushed and washed for use in plac of sand. It is thought from inspection that the conglomerate is har enough to make good sand, which can be ground to a uniform grad *and thoroughly* washed under pressure in a revolving cylinder.

U. S. GEOLOGICAL SURVEY



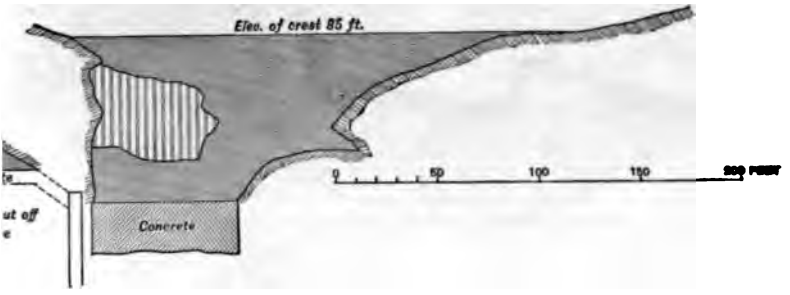


FIG. 26.—Downstream elevation, rock-filled dam, East Park dam site.

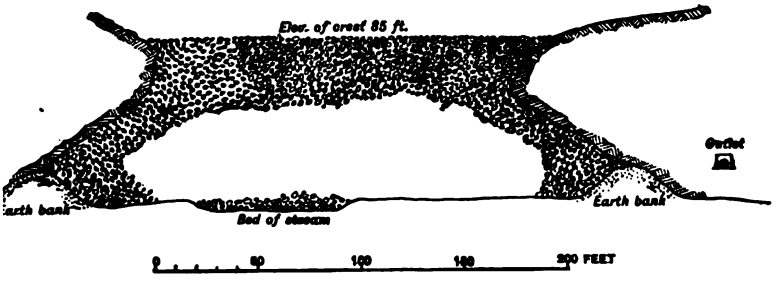
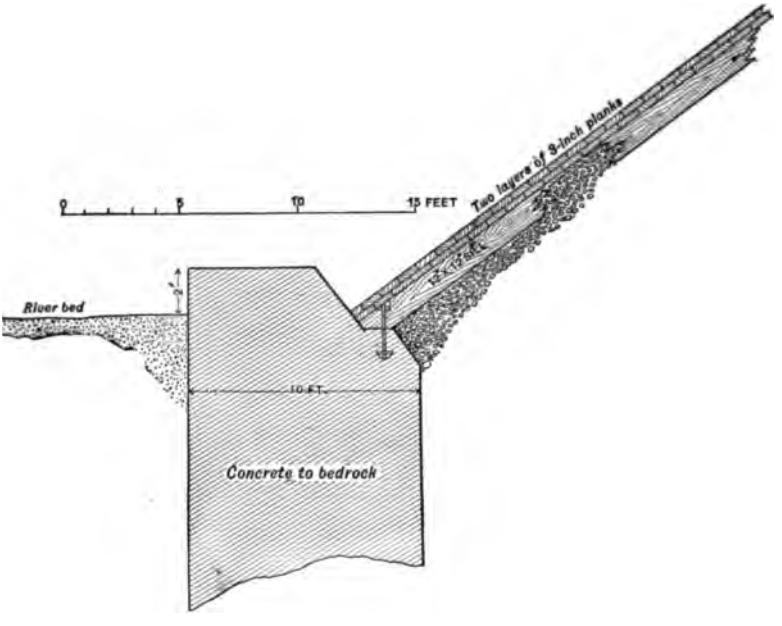


FIG. 27.—Upstream elevation, rock-filled dam, East Park dam site.



G. 28.—Detail of plank face, rock-filled dam, East Park dam site.

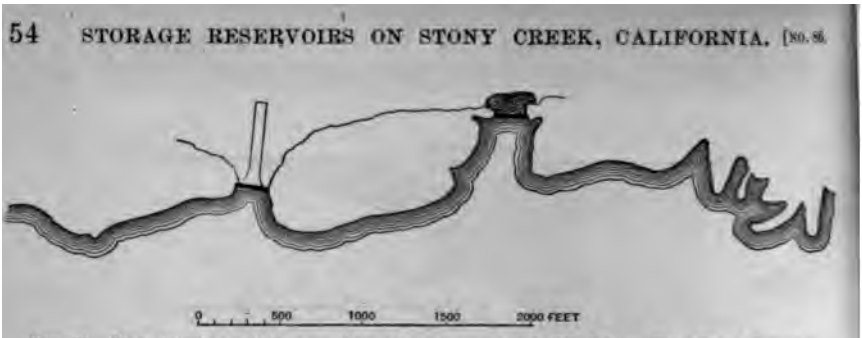


FIG. 29.—Plan showing relative position of wasteway, rock-filled dam, East Park dam site.

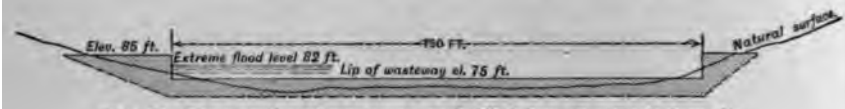


FIG. 30.—Cross section of wasteway, rock-filled dam, East Park dam site.

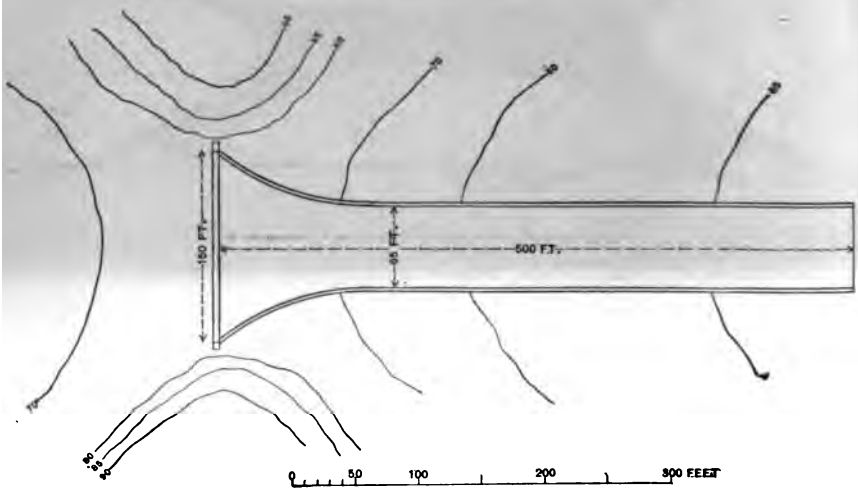


FIG. 31.—Plan of wasteway, rock-filled dam, East Park dam site.

The following figures have been used to estimate the cost of concrete in this locality:

Cost of concrete at Little Stony Creek.

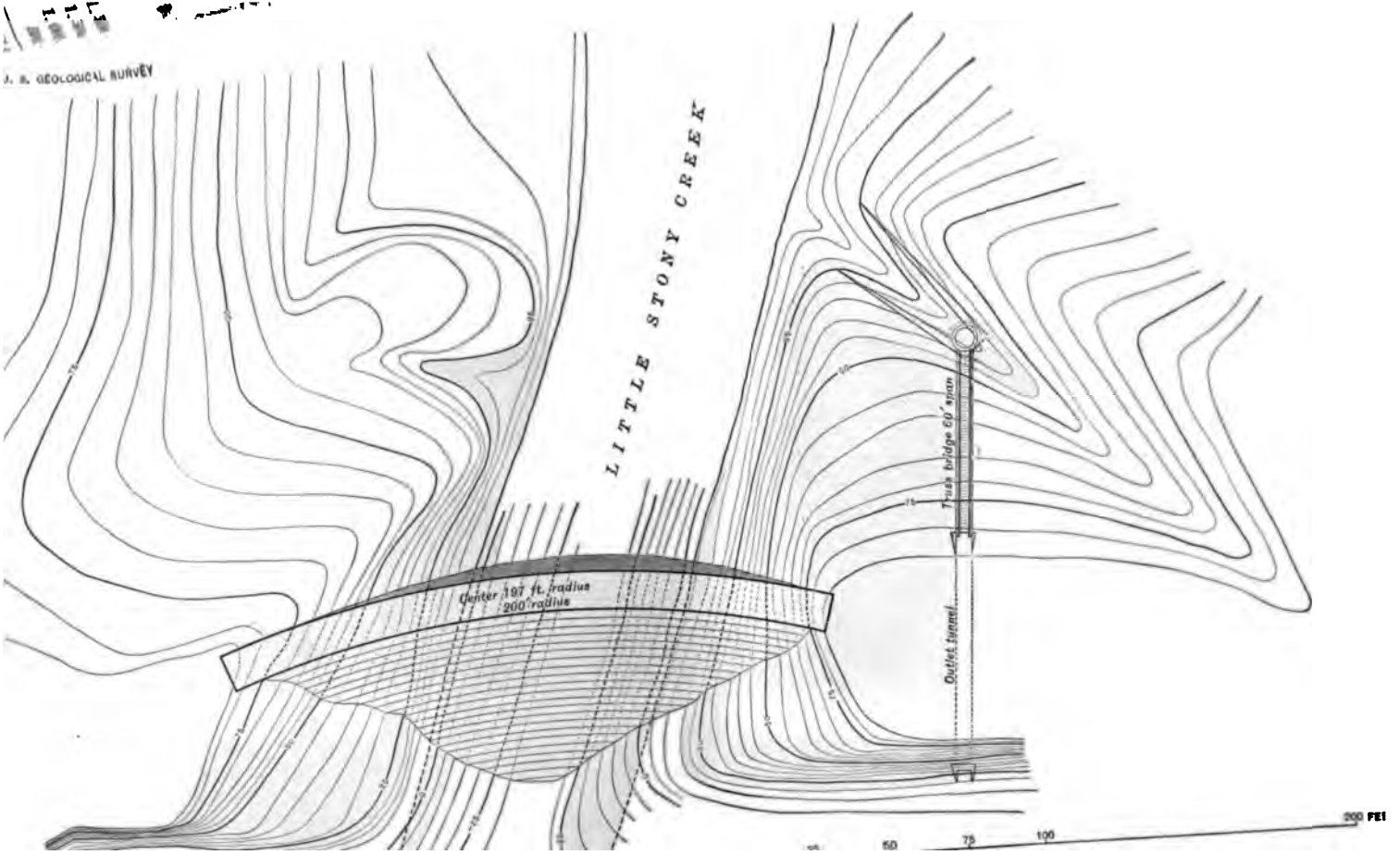
CEMENT.

1 barrel Portland cement, at railroad	$3.75	
Freight to dam, at 20 cents per 100 pounds	.80	
Cost delivered, per 375 pounds		$4.55

PLANT FOR PREPARING CONCRETE.

Mill for crushing rock	1,500.00
Mill for grinding coarse sand	1,500.00
Engine and boiler	1,000.00
Freight and setting up	500.00
Plant for preparing sand and rock for concrete	4,500.00
Machine for washing	1,000.00

U. S. GEOLOGICAL SURVEY



PREPARING ROCK AND SAND.

ε, crushing, per cubic yard	$1.50	
ε, washing, per cubic yard	.15	
		$1.65
l, grinding, per barrel	.36	
l, washing, per barrel	.14	
		.50

TOTAL COST PER YARD OF CONCRETE.

ε, 1 cubic yard	1.65
l, 2 barrels, at 50 cents	1.00
ent, 1 barrel	4.55
or, mixing	.50
or, placing in dam	1.00
w for machinery	.30
tingencies	1.00
Estimate total cost, per yard	10.00

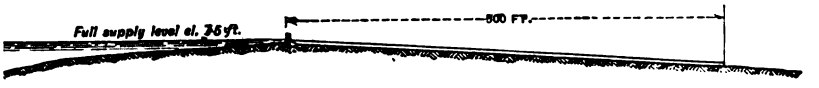


FIG. 32.—Profile of wasteway, rock-filled dam, East Park dam site.

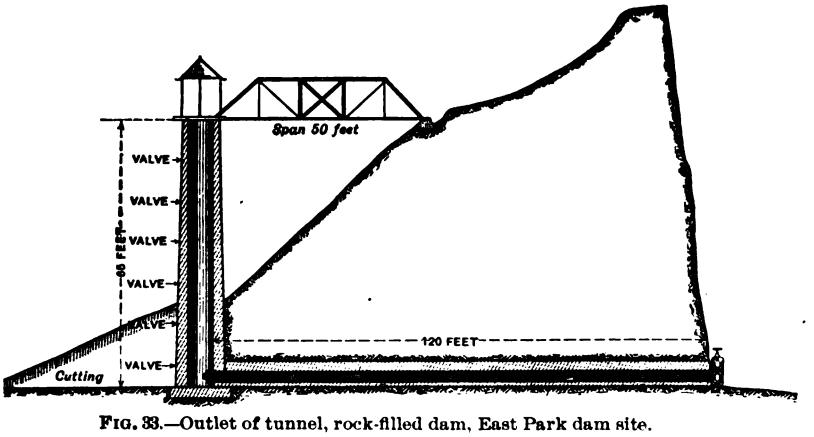


FIG. 33.—Outlet of tunnel, rock-filled dam, East Park dam site.

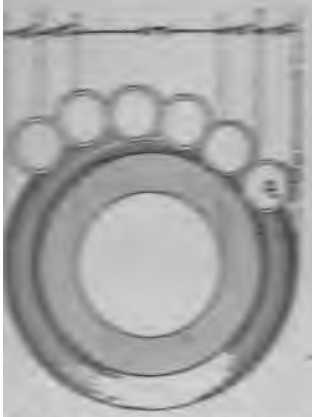


FIG. [illegible].—Plan of valves, rock-filled dam, East Park dam site.

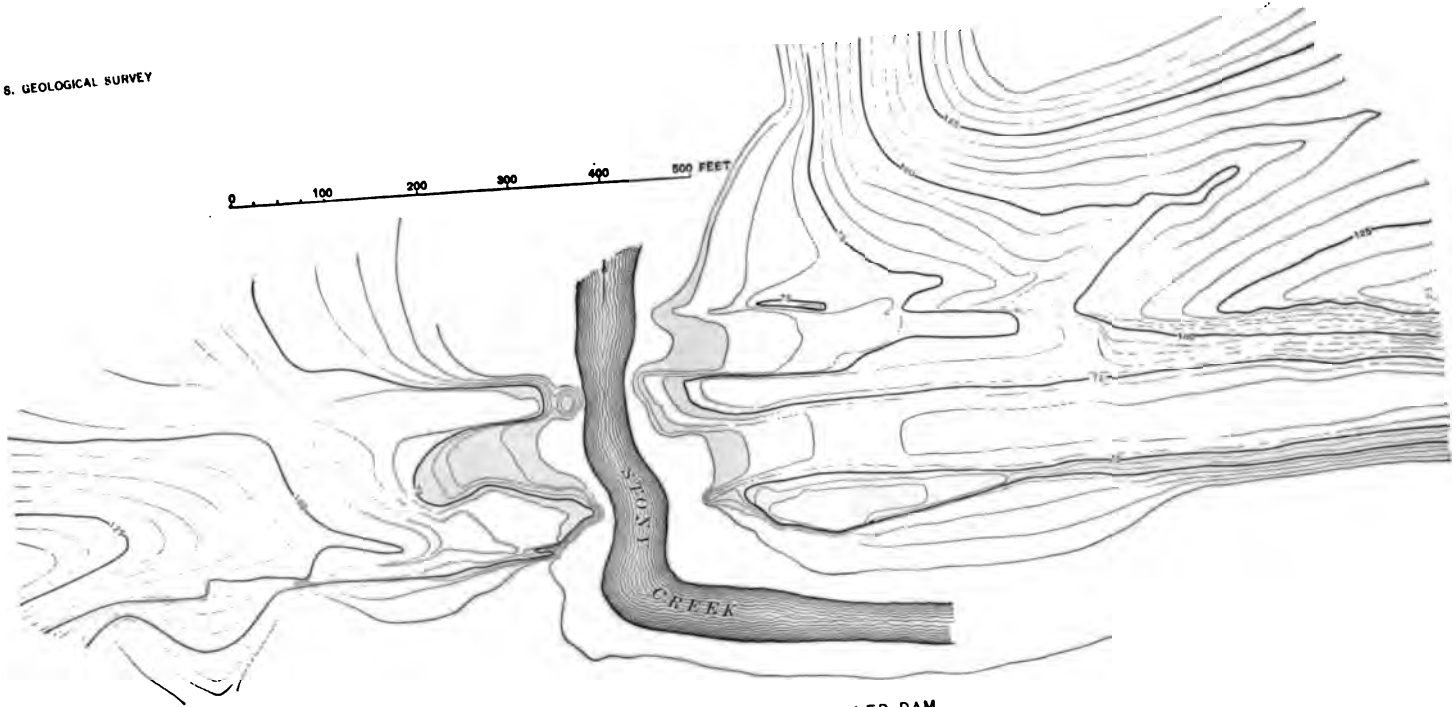
FIG. [illegible].—Tunnel cross section, rock-filled dam, East Park dam site.

MILL SITE.

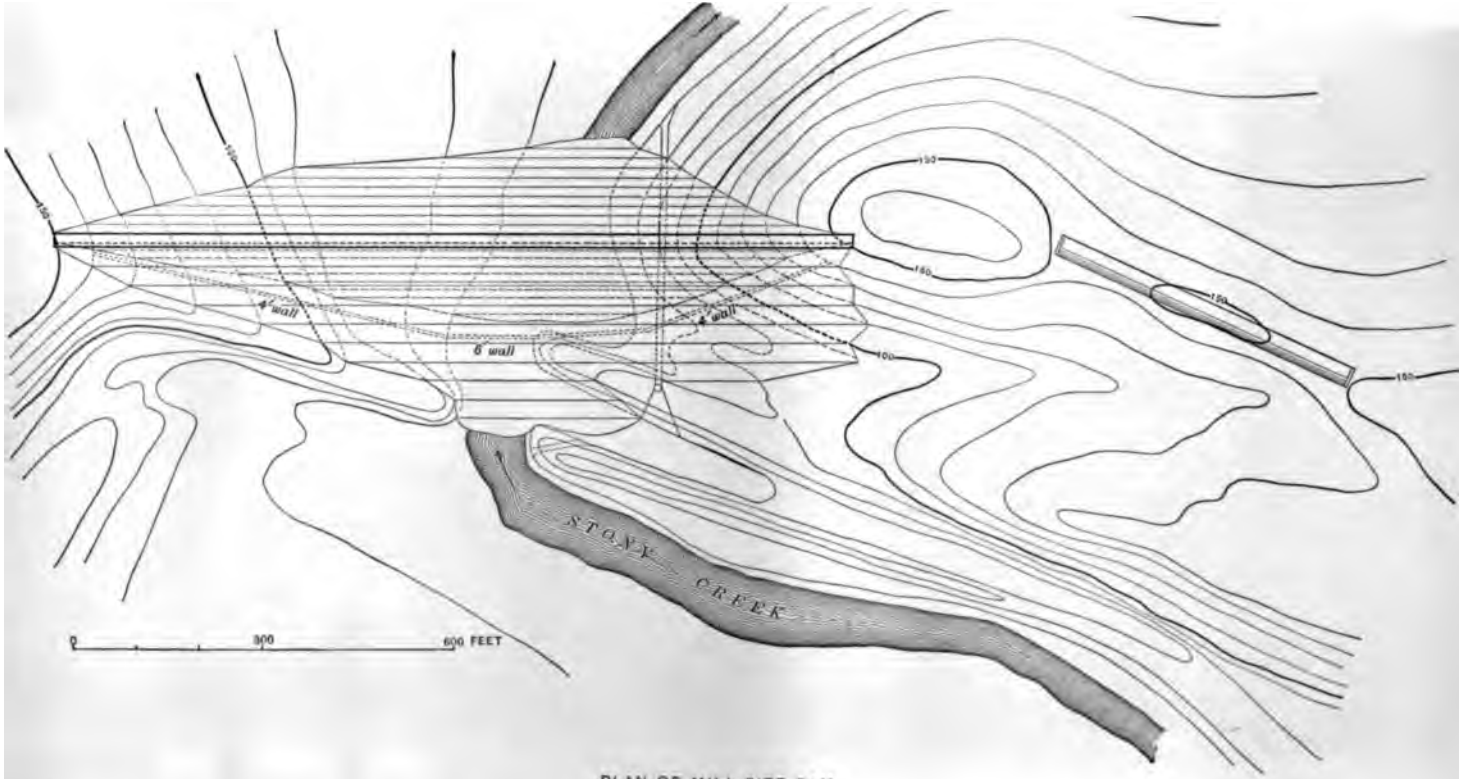
At a point on the main creek in sec. 1, T. 21 N., R. 6 W., Mount Diablo meridian, locally known as the "Mill Site," the main stream intersects a conglomerate bed.

As it is near the Sacramento Valley, and has back of it over 500 square miles of drainage area, exclusive of Briscoe and Little Stony creeks, this site is relatively important. A dam at this point, 95 feet above the stream bed, would impound 43,735 acre-feet of water. The drainage area above the site is such that it is estimated that this amount of water would be available even in dry years. A record of the flow has been kept at Julian's ranch at a point 1¼ miles above the dam site; the estimated discharge for 1901 and 1902 is shown by the table on p. 35. The depth to bed rock is assumed to be 35 feet. No soundings were made to determine this.

The wall rock is not very good, and material for concrete would have to be transported 1,[illegible] feet. Owing to these conditions it was decided to estimate on a loose or rock-filled dam with ample spillway. The dam designed has a top length of 1,240 feet, upper slope 1 to 1¼; lower slope 1½ to 1; the upper slope is to be faced with an earth embankment built against it with a slope of 3 to 1, the width of the rock on the top to be 15 feet and the earth 5 feet, making the finished crest 20 feet wide. The spillway, calculated to carry 36,250 second-feet of water when flowing 8 feet deep over the sill, is 500 feet wide by 10 feet deep, and would be located to the east of the dam through a low saddle, and discharge several hundred feet below the dam.



MILL SITE DAM SITE, ROCK-FILLED DAM.



PLAN OF MILL SITE DAM.

Estimate of cost of rock-fill dam at Mill Site.

,400 cubic yards earth and selected material, at 75 cents per cubic yard		$148,800
.200 cubic yards loose rock to be transported, average 1,600 feet, at $1		293,200
ncrete cut-off wall, 2,836 cubic yards, at $10	$28,360	
:cavation, 1,452 cubic yards, at $2	2,904	
:cavation, 951 cubic yards, at 50 cents	476	
		31,740
illway, 500 feet wide 10 feet deep:		
Excavation, 13,160 cubic yards, at 40 cents	5,264	
Concrete wall and apron for weir, 875 cubic yards, at $10	8,750	
		14,014
ıtlet tunnel, 400 feet, at $10		4,000
ɔwer, 90 feet, 1.7 cubic yards per foot, 153 cubic yards, at $10		1,530
alves and appliances		3,000
ɔncrete dam in tunnel, 100 feet, 85 cubic yards, at $10		850
0 feet 48-inch pipe and gate attached		2,000
ridge for tower, 225 feet span, Pratt truss		3,000
,340 cubic yards riprapping, at $1.50 (additional charge)		27,510
		529,644
per cent for contingencies and engineering		52,964
Total		582,808

'ost per acre-foot stored, $13.32.

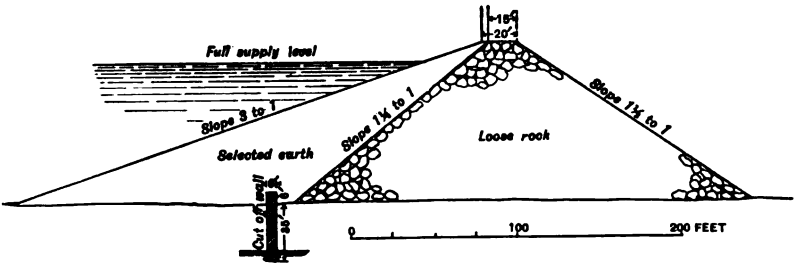


FIG. 36.—Section of Mill Site dam.

Capacity of Mill Site reservoir.

Contour.	Height of dam.	Area.	Capacity between contours.	Total capacity.
Feet.	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*
55	0	0	0	0
60	5	25.9	130	65
70	15	117.1	715	780
80	25	268.3	1,927	2,707
90	35	398.2	3,333	6,040
100	45	504.6	4,514	10,554
110	55	629.4	5,670	16,224
120	65	798.4	7,139	23,363
130	75	1,029.1	9,137	32,500
140	85	1,231.2	11,300	43,800

Elevation of outlet, 5 feet above bottom of reservoir.
Elevation of spillway, 85 feet above bottom of reservoir.
Capacity, 43,800—65=43,735 acre-feet.

This water would be used to irrigate the rich foothill lands on t west side of the Sacramento Valley between Orland and Willows.

In the judgment of the county assessor, who has an intimate kno edge of the nature of the land in Glenn County, these lands would easily advanced $30 per acre in value if furnished with ample w supply.

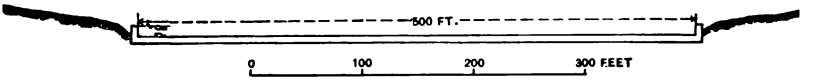


FIG. 37.—Section of spillway, Mill Site dam.

The capacity of the Mill Site reservoir not being sufficien impound all of the flow of Stony Creek, a further investigation made in February, 1901, of the feasibility of diverting a portio this water into Hambright and Eppinger creeks, small streams ri in the foothills and discharging into the Sacramento Valley. Cer reservoir sites exist on those streams too large to be filled from t drainage basins. The result of this investigation indicated that cost of the diversion-canal line would be too heavy and the reser capacity not sufficient to justify the necessary expense inciden this construction.

ALFALFA FIELD, BROWN'S RANCH, STONY CREEK VALLEY.

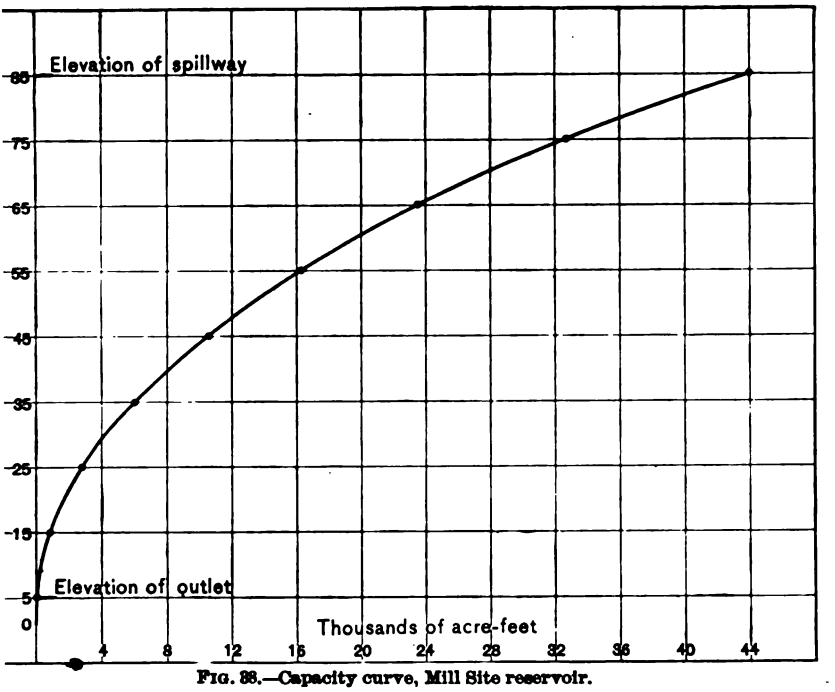


FIG. 38.—Capacity curve, Mill Site reservoir.

SUMMARY.

The annual cost per acre-foot of water stored is the important ult to obtain, and this is shown by the accompanying table for each ervoir and for each class of dam estimated upon.

Cost and capacity of reservoirs on Stony Creek.

provement.	Description.	Area of watershed.	Length of dam on crest.	Width of crest of dam.	Capacity.	Cost of installation.		Annual cost per acre-foot of water stored for interest and operation.
						Total.	Per acre-foot stored.	
		Square miles.	*Feet.*	*Feet.*	*Acre-feet.*			
coe reservoir.	125-foot concrete gravity dam with wasteway.	50	360	12	14,385	$218,281.80	$15.17+	$1.10
	120-foot concrete overflow dam.	50	360	16	14,385	211,105.95	14.67+	1.07
	125-foot loose rock-fill dam with wasteway.	50	360	20	14,385	205,652.00	14.29+	1.09
t Park reservoir.	115-foot concrete gravity dam with wasteway.	210	197	12	26,000	206,559.10	7.94	.58
	115-foot loose rock-fill dam with wasteway.	210	195	20	26,000	169,335.00	6.51	.50
l Site reservoir.	95-foot loose rock-fill dam with wasteway.	500	1,240	20	43,735	582,608.00	13.32	.93

Page.

Jellys Ferry, Sacramento River at, discharge of ..... [illegible]
Jellys Ferry, discharge measurements at ..... [illegible]
on Stony Creek, gage station at ..... [illegible]
precipitation at ..... [illegible]
Little Stony, precipitation at ..... [illegible]
Little Stony Creek, dam of various types on, estimates for ..... [illegible]
reservoir site on ..... [illegible]
Hardham, W. H., data from report of, concerning farm-land holdings ..... [illegible]
Hill Site, description and location of ..... [illegible]
dam at, estimated cost of ..... [illegible]
importance of ..... [illegible]
Hill Site dam, plan of, plate showing ..... [illegible]
section of, figure showing ..... [illegible]
section of spillway, figure showing ..... [illegible]
Hill Site dam site, on Stony Creek, plate showing ..... [illegible]
rock-filled dam, plate showing ..... [illegible]
Hill Site reservoir, capacity curve, figure showing ..... [illegible]
capacity of ..... [illegible]
Hill Site reservoir site, plate showing ..... [illegible]
Newville, reservoir site at ..... [illegible]
Orange tree at Willows, plate showing ..... [illegible]
Orland, climatological data for ..... [illegible]
Paskenta, reservoir near ..... [illegible]
Po, valley of, climatic conditions in, comparison of, with those of Sacramento Valley ..... [illegible]
Population of Colusa and Glenn counties ..... [illegible]
Precipitation, records of ..... [illegible]
Red Bluff, precipitation at ..... [illegible]
precipitation at, figure showing ..... [illegible]
Sacramento River at, discharge of ..... [illegible]
temperature at, summaries of ..... [illegible]
thunderstorms at, number of ..... [illegible]
weather at, conditions of ..... [illegible]
Riverside district, irrigation in, results of ..... [illegible]

Page.

Sacramento River, discharge of, at Iron Canyon ..... [illegible]
discharge of, at Jellys Ferry ..... [illegible]
at Red Bluff ..... [illegible]
difficulty of diverting waters of ..... [illegible]
opposite Willows, plate showing ..... [illegible]
Sacramento Valley, climatic conditions in ..... [illegible]
climatic conditions in, comparison of, with those of northern Italy ..... [illegible]
farming conditions in ..... [illegible]
frosts in, killing, dates of ..... [illegible]
population of ..... [illegible]
proposed forest reserve in ..... [illegible]
rainfall, temperature, and relative humidity in ..... [illegible]
rainfall in, greatest amount of, table showing ..... [illegible]
streams of, fluctuations of ..... [illegible]
water supply of ..... [illegible]
Sacramento Valley Development Association, resolutions by ..... [illegible]
Salt Creek, description of ..... [illegible]
Sand on Little Stony Creek, scarcity of ..... [illegible]
Stony Creek, discharge of ..... [illegible]
reservoirs on, cost and capacity of ..... [illegible]
silt carried by ..... [illegible]
storage possibilities of ..... [illegible]
Stony Creek (North Fork), reservoir on ..... [illegible]
Storage possibilities of Stony Creek Basin ..... [illegible]
Thomas Creek, possibility of diverting water of ..... [illegible]
Topography of Stony Creek Basin ..... [illegible]
Water and Forest Association, resolutions by ..... [illegible]
Weaverville, precipitation at ..... [illegible]
Willows, climatological data for ..... [illegible]
ranch house and wheat farm in Sacramento Valley near, plate showing ..... [illegible]
temperature at ..... [illegible]
Woodlands, precipitation at ..... [illegible]
precipitation at, figure showing ..... [illegible]
temperature at ..... [illegible]

O

Supply and Irrigation Paper No. 87 Series I, Irrigation, 15

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

IRRIGATION IN INDIA

(SECOND EDITION)

BY

HERBERT M. WILSON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

Page.
Jellys Ferry, Sacramento River at, discharge of 16-18
Julian's ranch, discharge measurements at 33-35
on Stony Creek, gage station at 32
precipitation at 24
Little Stony, precipitation at 24
Little Stony Creek, dam of various types on, estimates for 49, 51
reservoir site on 47-56
Markham, W. H., data from report of, concerning farm-land holdings 13
Mill Site, description and location of 56-59
dam at, estimated cost of 57, 59, 60
importance of 56
Mill Site dam, plan of, plate showing 56
section of, figure showing 57
section of spillway, figure showing 58
Mill Site dam site, on Stony Creek, plate showing 50
rock-filled dam, plate showing 56
Mill Site reservoir, capacity curve, figure showing 59
capacity of 58, 59-60
Mill Site reservoir site, plate showing 52
Newville, reservoir site at 36
Orange tree at Willows, plate showing 10
Orland, climatological data for 28
Paskenta, reservoir near 37
Po, valley of, climatic conditions in, comparison of, with those of Sacramento Valley 11
Population of Colusa and Glenn counties 13
Precipitation, records of 23-26
Red Bluff, precipitation at 30
precipitation at, figure showing 27
Sacramento River at, discharge of 15
temperature at, summaries of 29
thunderstorms at, number of 32
weather at, conditions of 31
Riverside district, irrigation in, results of 13-14

Page.
Sacramento River, discharge of, at Iron Canyon 18
discharge of, at Jellys Ferry 16-18
at Red Bluff 15
difficulty of diverting waters of 9
opposite Willows, plate showing 14
Sacramento Valley, climatic conditions in 28
climatic conditions in, comparison of, with those of northern Italy ..... [illegible]
farming conditions in ..... [illegible]
frosts in, killing, dates of ..... [illegible]
population of ..... 13-[illegible]
proposed forest reserve in ..... 20-[illegible]
rainfall, temperature, and relative humidity in ..... 10-[illegible]
rainfall in, greatest amount of, table showing 31
streams of, fluctuations of 10
water supply of 10-12
Sacramento Valley Development Association, resolutions by 20
Salt Creek, description of 38
Sand on Little Stony Creek, scarcity of 52
Stony Creek, discharge of 32-35
reservoirs on, cost and capacity of 59-60
silt carried by 35-36
storage possibilities of 36
Stony Creek (North Fork), reservoir on 36
Storage possibilities of Stony Creek Basin 36
Thomas Creek, possibility of diverting water of 36-37
Topography of Stony Creek Basin 19-20
Water and Forest Association, resolutions by 20
Weaverville, precipitation at 25
Willows, climatological data for 28
ranch house and wheat farm in Sacramento Valley near, plate showing 12
temperature at 27
Woodlands, precipitation at 26
precipitation at, figure showing 27
temperature at 27

O

Water-Supply and Irrigation Paper No. 87 Series I, Irrigation, 15

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

IRRIGATION IN INDIA

(SECOND EDITION)

BY

HERBERT M. WILSON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

CONTENTS.

	Page.
eface	7
eface to second edition	9
troduction	11
List of works on Indian irrigation	25
APTER I.—Finance and statistics	29
Value and necessity of irrigation	29
Land and crops	35
APTER II.—Topography, meteorology, and forestry	39
Topography and geology	39
Meteorology	43
Forestry	45
APTER III.—History and administration	47
History of irrigation works	47
Administration and legislation	48
APTER IV.—Extent and character of irrigation	56
Classes of works	56
Extent of irrigation	57
Financial and agricultural results	58
APTER V.—Alkali and duty	63
Objections to irrigation	63
Water duty and evaporation	67
APTER VI.—Wells, inundation and deltaic canals	75
Wells	75
Inundation canals	78
Deltaic canals	81
APTER VII.—Perennial canals	88
Source of supply	88
Ganges canal, Northwest Provinces	89
Lower Ganges canal, Northwest Provinces	93
Agra canal, Northwest Provinces	95
Sirhind canal, Punjab	97
Chenob, Bari Doab, and Western Jumna canals, Punjab	99
Sidhnai canal, Punjab	100
Soane canals	101
Cross section, slope, and alignment	104
Head-works	107
Weirs	109
Scouring sluices	119
Canal regulators	124
Well foundations	130
Escapes	132
Falls and rapids	134
Drainage works	137
Distributaries	144
Methods of *applying water*	150

CHAPTER VIII.—Storage works
Classes of works
Reservoirs
Mutha project
Nira project
Betwa project
Periyar project
Tansa reservoir
Masonry dams
Design of dams and weirs
Cost of labor and material
Tanks
Ekruk tank
Ashti tank
Tank dams
Combined storage and canal systems
Palar anicut system
Russellkonda tank, Rushikulya project
Zhara Karez irrigation project
CHAPTER IX.
River training and land reclamation:
River conservancy
Land reclamation

ILLUSTRATIONS.

		Page.
ATE I.	Map of India	11
II.	Aden tanks, Arabia	22
III.	Mot	74
IV.	*A*, Persian wheel; *B*, Paecottah	76
V.	*A*, Kistna anicut, with river in moderate flood; *B*, Head-sluices of eastern channel from Kanigiri reservoir	84
VI.	Kanigiri reservoir escape	86
VII.	Gopalpur bifurcation, Ganges canal	92
VIII.	Sirhind canal system	98
IX.	Soane canal system, Bengal	102
X.	Cross sections of modern weirs	112
XI.	Narora weir, Lower Ganges canal; plan of well foundations	114
XII.	Narora weir, Lower Ganges canal; plan of superstructure	116
XIII.	Head-works, Lower Ganges canal, Narora	120
XIV.	Sinking foundation wells, Nadrai aqueduct, Lower Ganges canal	130
XV.	Asafnagar Falls, Ganges canal	134
XVI.	Solani aqueduct, Ganges canal	138
XVII.	Ranipur superpassage, Ganges canal	140
XVIII.	Rutmoo level crossing, Ganges canal	142
XIX.	Bhatgur dam, Nira system, Bombay	164
XX.	*A*, Vir head-works, Nira system, Bombay; *B*, Kurra aqueduct, Nira canal	168
XXI.	Main and subsidiary weirs, Nira system; Vir in great flood	170
XXII.	Plan of Periyar project, Madras	180
XXIII.	Periyar dam during construction	182
XXIV.	*A*, Foundation, Tansa dam; *B*, Carrying stones to build Tansa dam	186
XXV.	Natives building Tansa dam, Bombay	188
XXVI.	Ekruk tank	204
XVII.	*A*, Russellkonda head sluice; *B*, Russellkonda dam	216
IG. 1.	Percolation and evaporation	69
2.	Paecottah	76
3.	Persian wheel	77
4.	Single mot	77
5.	Inundation canal heading in Dund	79
6.	Kistna canal system	84
7.	Plan and profile of Ganges canal, Hardwar to Roorkee	91
8.	Thora Nulla aqueduct, Soane canal	102
9.	Canal cross sections	105
10.	Three ancient weirs	109
11.	Plan of Soane weir	114
12.	Plan of head-works, Soane canals	115
13.	Shutter on Soane weir	116

Page.
FIG. 14. Sidhnai weir ... 116
15. Sidhnai canal; section of river in line of dam ... 117
16. Details of temporary dams, Ganges canal heads ... 118
17. Myapur dam, Ganges canal ... 120
18. Head-works and weir training works, Ganges canal ... 121
19. Dropping the Soane automatic sluices ... 122
20. Details of Sidhnai weir ... 123
21. Regulating gates, Ganges and Jumna canals ... 125
22. Narora weir, Lower Ganges canal, detail of canal sluices ... 126
23. Head-works, Ganges canal ... 127
24. Regulating gates, Soane canal head ... 128
25. Soane canal, automatic sluice gate ... 129
26. Ogee and vertical falls, Ganges canal ... 134
27. Soane canals, Bengal; arrangement of branches and escape at Dunwar ... 136
28. Rapids, Bari Doab canal ... 138
29. Cross section of Solani aqueduct, Ganges canal ... 139
30. Agra canal, cross section of Kushuk Fall ... 142
31. Plan of Rutmoo crossing, Ganges canal ... 143
32. Kao Nulla siphon aqueduct, Soane canal ... 144
33. Longitudinal section of Nadrai aqueduct, Ganges canal ... 145
34. Cross section of Nadrai aqueduct, Ganges canal ... 145
35. Plan of distributing head, Mutha canal, Bombay ... 148
36. Sasoon superpassage, Sirhind canal ... 149
37. Drainage map, showing arrangement of distributaries ... 154
38. Standard masonry outlet for distributaries, Punjab ... 156
39. Plan of Mutha and Nira irrigation projects, Bombay ... 161
40. Plan and cross section of Bhatgur dam, Nira system, Bombay ... 165
41. Reinolds automatic weir gate ... 166
42. Section of automatic gates and crest Bhatgur dam ... 167
43. Detail of automatic gate ... 168
44. Plan of head-works, Nira canal, Vir ... 169
45. Plan and section of head, Nira canal ... 170
46. Nira canal; superpassage at siphon for Jewhar Nulla ... 171
47. Betwa project; plan of dam and head-works ... 175
48. Cross section, Betwa dam ... 176
49. Betwa project, plan of regulator and scouring sluices ... 177
50. Automatic drop shutters, Betwa dam ... 178
51. Shutter gates, Betwa dam ... 179
52. Section of Periyar dam ... 182
53. Periyar head-works, plan of dam and escape ... 183
54. Tansa dam, Bombay ... 186
55. Tansa project, longitudinal section of dam ... 187
56. Profile of masonry dam, Molesworth's formula ... 192
57. Cross sections, earth and combined dams ... 198
58. Map showing Ashti tank ... 207
59. Ashti tank dam ... 208
60. Ashti dam slips ... 213
61. Palar Anicut system ... 215
62. Palar Anicut system, plan and cross section ... 216
63. Zhara karez irrigation project, Beluchistan ... 218
64. Moncha Nulla karez ... 219
65. *Training* works, Lower Ganges canal, Narora ... 222
66. *Training* works, Agra canal, Okhla ... 223

PREFACE.

In the following account of some of the more interesting and prominent irrigation works in India I shall confine my detailed descriptions, as I did my observations, to the works which exist under conditions similar to those in the United States, and shall refer only briefly to the other though equally important features of the irrigation problem in India.

I examined only the principal canals, navigable and nonnavigable, and entirely neglected the deltaic and inundation canals, as there is little or no probability that such works will ever be constructed in the United States. Transportation by railways and wagon roads is so easy and general all over our country that there is little likelihood our canals will ever be made navigable; accordingly, though I saw and examined several navigable canals, little reference will be made to their features. The more important reservoirs and tanks were examined, especially those under construction. Little will be said of wells, though in the future improved methods of pumping will be used in the United States.

India stands preeminent for her gigantic engineering undertakings. No other country has so vast and so fertile an expanse of territory, with such convenient slopes for the construction of canals, and at the same time such an abundant water supply. In general there is great similarity between the climate and topography of the great northern plains of India and portions of our arid West, especially the eastern slope of the Rocky Mountains and the great California Valley. Central India and the Deccan have many features in common with the central portion of the arid region, particularly portions of northern Arizona and southern Utah. The climate is as similar to that of our Middle Western States as is the topography. The average annual precipitation rarely exceeds 30 inches, while the precipitation during the autumn, or rabi, crop varies between 2 and 6 inches.

This autumn crop is the one that will be generally considered and discussed in this report, since during the time of its maturity the climatic conditions are very similar to those existing everywhere in the arid regions of the United States. Two crops are annually grown in India, one of which is sown in early spring at the beginning of the monsoon or rainy season, and is called the summer or kharif crop.

This crop depends little on irrigation for its maturing, as t
proportion of the rain of the entire year falls during the sum
the autumn, however, the rainfall is very light, and, as befo
the temperature and precipitation are both similar to th
West.

Though the conditions of government and people are so d
India from those in America, many useful examples and lesso
drawn from the method of administration and legislation practi
as well as from the financial success or failure that has att
construction of their works. The conditions under which A
must undertake irrigation enterprises are not so different f
existing in India and southern Europe as would at first appe
works we may construct must depend for their utilization an
on immigration, as they will be largely in a sparsely inhabite
In order to induce this immigration people must be convin
benefits and utility of irrigation. Conditions similar to t
in portions of India where the most successful irrigation
have been carried out. Irrigation works have frequently be
taken in portions of India that were already overpopulat
have rendered the land more fertile and sufficiently producti
port nearly double the population which it was previously
sustaining. This, too, has been accomplished despite the pre
be overcome, and the difficulties encountered in inducing peop
use of the water furnished; difficulties far greater than we w
to contend with in inducing immigration to our arid West.
the great canals of the Northwest Provinces and the Pu
undertaken in districts that were sparsely inhabited. Th
are among those of India that have paid the largest intere
original outlay. Within ten years from their construction th
was fully populated, although the immigration was often fro
portions of India.

Any imperfections which may appear in this account of
amined and in operation are in no way due to lack of assist
the engineers in authority. It is impossible to speak strong
of the hospitality and kindness with which I was everywher
In fact, owing to the limited time at my disposal, the grea
culty experienced was to leave the hospitable guides and ent
who were apparently willing to spend days in showing and e
the works they had in charge.

PREFACE TO SECOND EDITION.

This account of some of the more important irrigation works of India was first published in Part II of the Twelfth Annual Report of the Director of the United States Geological Survey, for 1890–91. The demands for this report were so great that the entire edition was exhausted within a few years. Recently, and largely as a result of the renewed activity in irrigation in the Western States through the creation by Congress of the Reclamation Service of the United States Geological Survey, there have been increased calls for this report. At the instance of Mr. F. H. Newell, chief engineer of the Reclamation Service, I have made a careful revision of this report from such available data as I have succeeded in accumulating during the intervening years. This edition is published as one of the series of Water-Supply and Irrigation Papers of the Geological Survey.

Comparatively few new works have been built in India since 1890. The Bhatgur and Tansa dams have been finished and are in successful operation with but slight modifications from the plans as previously published. The great Peryiar project has been completed with slight modifications. These changes are noted in the accompanying text. In addition, the matter concerning inundation canals and that descriptive of deltaic canals have been extended. Under the latter head the Kistna project is described in more detail, as is the Sangamanicut project, both of which contain works which will interest American engineers. Under title of "Tanks" the Rushikulya project is described, both because of the interest attached to the dam and because it is a combined project including the diversion of water from a running stream and its storage in a reservoir located at a considerable distance from the canal head.

The most important feature of the revision is the bringing of all the financial and statistical data concerning the more important works in each province up to 1901, the date of the last official Indian reports. At the close of 1901 the area of India, including native States, was 1,559,603 square miles, the total population was 294,266,701, and the total expenditure upon all classes of irrigation works by the Government of India had been $337,850,000. In the year 1900–1901 the expenditures on account of irrigation amounted to $11,500,000 and the revenues to $12,075,000, showing a profit of 7.5 per cent on the capital outlay for *construction*. The total area cultivated in India the same

year was 180,151,093 acres, and the total area irrigated was 18,611,106 acres, or, counting areas double cropped or those irrigated more than once in a season, the area irrigated was 33,096,031 acres. The estimated value of the irrigated crops in 1900–1901 was $150,000,000, and of these it is interesting to note that the area under cultivation in wheat amounted to over 16 million acres, and in cotton to over 8½ million acres, and that the total value of the latter crop alone was $52,773,000.

Construction, including in large measure repairs, was most active during the past few years, in order to afford employment in famine-stricken regions. The demands on the water stored in reservoirs in the semihumid portions of India—those which had been afflicted with drought and consequent famine during the last few years—were greater than ever before. Some of the more notable tanks in Bombay and central India were called upon to do their highest duty, and in consequence many of those projects which were constructed as protective works and were never anticipated to be revenue producing have recently earned moderate net revenues.

H. M. W.

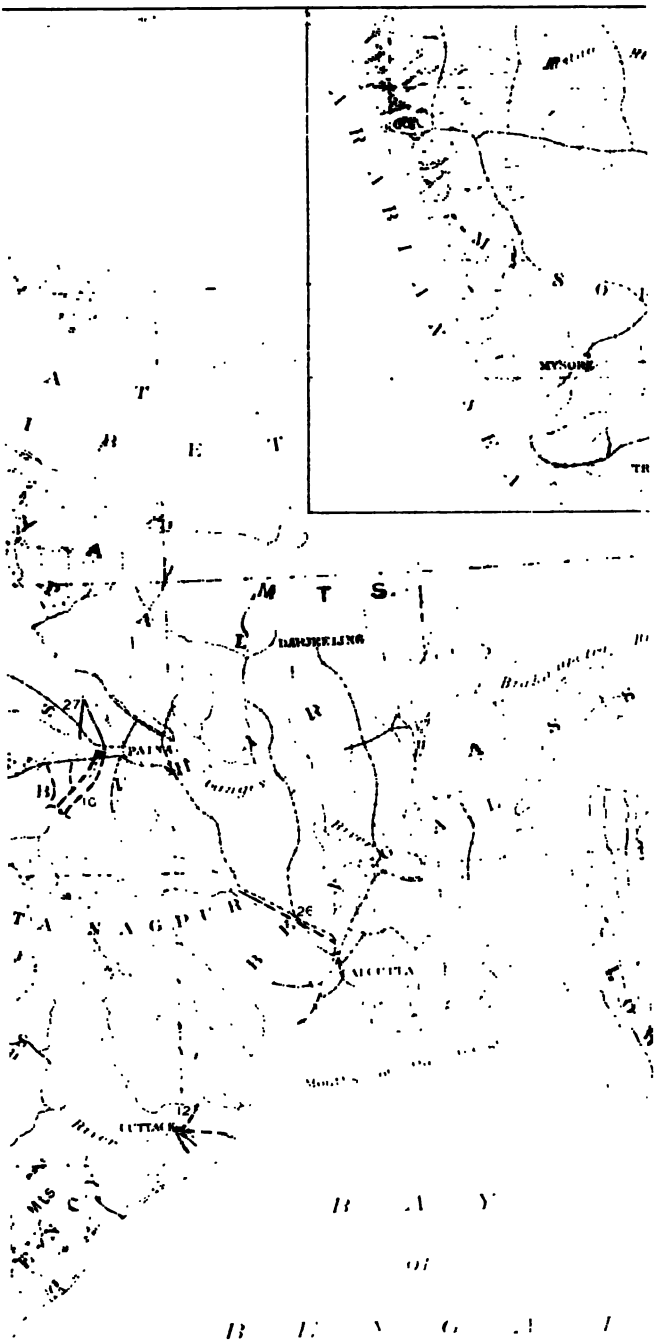
WASHINGTON, D. C., *December 22, 1902.*

u
u
a
or
ou

g a
ola
b
tw
tr
s a

ied
r
cre
ter
cer
dis
y o
ool
y o
s, a
ned
ber

ern-
and
resi-
resi-
Mr.
ived
eded


MYSORE
DARJEELING
PATNA
ALCUTTA
CUTTACK
27
26
12
B A Y
of

year
acre
once
mate
of th
whe
milli
$52,7

Co
duri
stric
the
with
grea
and
cons
tecti
have

W

IRRIGATION IN INDIA.

By HERBERT M. WILSON.

INTRODUCTION.

The principal sources from which the information in the accompanying report was obtained were (1) conversation with engineers in charge of works and examination of their office material, (2) personal examination of the works themselves, and (3) books and official reports. In the following narrative I will endeavor to sketch hastily the route traveled and give a brief outline of works visited.

For a week before my departure I was busily engaged in reading all the books and reports on Indian irrigation procurable, in order to plan the trip so as to see the most in the least space of time, for I had but five months for the entire journey. I finally decided that the two months spent in India should be devoted to the northern and central portions, and the route was planned so as to see only such works as were within easy access of the railway lines.

Through the cooperation of the director of the United States Geological Survey I was enabled to leave Washington on December 1, 1889, well equipped with letters of introduction to the various secretaries of the public works departments of India, carrying also letters from the Secretary of State to our diplomatic and consular officers abroad. In New York letters of introduction to prominent English engineers were obtained from the secretary of the American Society of Civil Engineers and others, and on December 4 I sailed for Liverpool.

A few days were spent in London, where, through the courtesy of Mr. James Forrest, secretary of the Institution of Civil Engineers, a number of letters of introduction to Indian officials were obtained. From London I proceeded to Brindisi, Italy, and embarked December 30 for Bombay, arriving there on January 13, 1890.

In Bombay I called upon Mr. W. C. Hughes, secretary to government for the irrigation branch of the public works department, and he gave me letters to several of the engineers in the Bombay Presidency, and kindly aided me in so arranging my tour in that presidency as to see only such works as were most accessible. From Mr. W. Clerke, chief engineer of the Bombay waterworks, I also received much valuable assistance and advice, and on January 18 I proceeded

to Poona with the intention of visiting the Fife reservoir. In the absence of the chief engineer, Colonel Cruikshank, R. E., Mr. Rebsch, executive engineer of the Mutha canals, devoted two or three days to showing me over the works under his charge.

We drove from Poona to Lake Fife, a distance of 12 miles up the valley of the Mutha River. The road here, as everywhere in India, was excellent, being well macadamized for the entire distance. On both sides were well-cultivated fields, the principal crops grown being sugar cane, millet, and wheat, and the care with which the water was applied to these crops was the first object which attracted attention. I also observed that Indian peasants fully appreciated the value of fertilizers. The city officials of Poona make a handsome profit annually by removing excrement from the residences and mixing it with ordinary soil, the whole being sold by the cartload to farmers.

Lake Fife is a large artificial reservoir, formed by a dam three-quarters of a mile long and nearly 100 feet in height. The water is backed up the valley for nearly 15 miles, and the available storage capacity of the lake is about 63,000 acre-feet. The Mutha canals are taken from the dam at the lower end of the lake, one along the right and the other on the left bank of the Mutha River. The right-bank canal is nearly 100 miles long and passes through the city of Poona, which it supplies with water; it is also used in irrigating the rich land lying between it and the river. The left-bank canal is much shorter, and also controls a large area of valuable land.

The topography of the Upper Mutha Valley seemed very familiar. Had I been suddenly transported in my sleep to northeastern Arizona the similarity of the topography of the two regions could not have more strikingly impressed me. At Lake Fife the Mutha River makes its exit through a narrow canyon similar to those of the mesa country in northern New Mexico and Arizona, and flows thence through a broad and gently sloping valley, which gradually widens till it becomes an extensive plain. The slope from the bottom of the stream toward the surrounding hills is regular, but rather steep, and suddenly terminates at the foot of cliffs which are similar in their abruptness and sharpness of outline to the mesa cliffs of our Southwest. The soil in the Mutha Valley is rather shallow, and wherever uncultivated is covered with a low, scrubby grass, dried and parched by the sun. At the canal edge the barren slopes are suddenly merged into endless green and well-cultivated fields. The slopes of the hills are rocky and barren, covered with a growth of low trees, among which babul or mesquite is the most prominent.

After examining Lake Fife, Mr. Rebsch and myself proceeded down the line of the Mutha canal and followed some of the minor distributaries through the fields, watching their ramifications, until we reached the smallest private ditch used in irrigating the crops. The construction of these canals is similar to that of small canals in the United

gates. The chief feature noticed was the substantial method of constructing all bridges, head-gates, and other regulators. Here, as elsewhere in India, timber is seldom used, owing to its cost and the rapidity with which it is destroyed by insects and rot. All bridges on this canal are constructed of masonry, and the smallest regulating gates consist of masonry passages let into the banks of the canal and closed with iron shutters. The system of distribution of the water is very complete every square foot of desirable land being under cultivation.

On January 21 I engaged a tonga, a sort of dogcart, drawn by a team of ponies, in which a three days' trip to Bhatgur reservoir and the Nira canals was made. The trip to Bhatgur was made in the night in order to avoid the heat. The road is macadamized the entire distance, and is lined on each side with a double row of trees, which furnish a dense and agreeable shade. The gradients are sufficiently easy for a railway, while all drainage passages, large or small, are crossed by masonry bridges. In order to avoid excessive grades a range of low hills about halfway in the journey is pierced by a tunnel nearly one-fourth of a mile long. This tunnel is about 20 by 20 feet in cross section, and is lined with masonry throughout.

At Bhatgur I was met by Mr. H. Beale, assistant engineer in charge of construction of the dam. During the day we went over the entire length of the dam and viewed all the works of construction. It was my good fortune to see the Bhatgur dam when it was about two-thirds completed and while the construction was being vigorously pushed. I was thus enabled to examine with care the details not only of the method of masonry construction, but also the management and character of the labor employed.

The topography above the Bhatgur dam is very similar to that at Lake Fife. The dam is constructed on a modern cross section, similar to that obtained by the Bouvier or the Rankine formula. It is located in a rather wide part of the river, the object being to afford sufficient spillway for the large volume of water which comes down the river in the spring floods. Its length is 4,067 feet and its greatest height is 130 feet above the foundations. The river at this point is subject to maximum floods of 50,000 second-feet. This reservoir is used as a storage basin to supply the Nira canals, which are taken from the Nira River at Vir, a point 20 miles below the dam. During my visit to Bhatgur 1,500 laborers were employed on the work and completed about 5,000 cubic feet of rubble and concrete masonry per day and 1,000 cubic feet of finished dressed-rubble facing. Stone for the construction of the dam was quarried close to the abutments, and kunkar, a dirty lime which produces a very good hydraulic cement, was found within a short distance of the dam site. Sand was procured from the river bed and charcoal for burning was obtained in the adjacent hills.

On the morning of the 22d I left Bhatgar, proceeding by tonga to Vir, the head of the Nira canal, where I was met by Mr. W. H. Le Quesne,

executive engineer in charge of the Nira system. The next two days were spent in looking over the reports and detailed maps in the office, in examining the great diversion weir at the head of the Nira canal, and inspecting the first 12 miles of the latter. The Vir weir is constructed throughout of concrete, faced with dressed-rubble masonry, and is 2,340 feet in length and 40 feet in greatest height above the river bed. A few hundred yards downstream is a subsidiary weir, similar in construction to the first, but only 615 feet long and 20 feet in height. This lower weir backs the water up against the toe of the upper one, thus producing a water cushion, on which the great floods fall harmlessly. The maximum flood over this weir may be 160,000 second-feet, when the water will be about 8 feet in depth on the crest of the main weir. Our trip down the canal was made in a rowboat, and we were thus enabled to examine several aqueducts and a siphon on the way. The first 10 miles of the canal are for diversion line only, being required in making grade to get the canal out of the confining banks of the Nira River. At about the tenth mile the first distributary is taken off to the irrigable lands.

On January 23 I left Vir for Lonand, where I took the train for Poona. This trip is one of the most interesting in India, the road passing through the celebrated Bhore Ghauts, a range of rugged, bluffy hills which break down precipitately to the western ocean. The summit of these Ghauts forms the edge and top of the great interior plateau of the Deccan. The scenery along the entire descent is similar in every respect to that east of the line of the Southern Pacific Railroad near Red Bluff. The road runs with heavy grades and sharp curves along the edges of nearly vertical trap cliffs, in a place that in almost any other country would be considered quite impracticable for railway construction. The expense of such a line in the United States would exceed $100,000 per mile. Owing to the very heavy rainfall which averages 250 inches per annum, the greatest precautions have been taken for the passage of all drainage lines. Numerous viaducts are crossed in rapid succession, the frequency of their recurrence being rivaled only by that of the many tunnels, there being 33 of these in a few miles.

I had been very desirous of making a visit to the celebrated Tansa reservoir, near Bombay, in the company of Mr. Clerke, the chief engineer, and on arriving in Bombay, on the 24th, I found he had arranged a trip with the governor of Bombay, Lord Reay, a few of the municipal officers, the governor's staff, Mr. Baldwin Latham, and myself. We left by special train on the evening of the 24th, arriving at Atgoan on the following morning. From Atgoan we had a pleasant tonga trip of 7 miles to the site of the Tansa dam. Here I was as fortunate as at Bhatgur. I found the great dam more than half completed and construction being vigorously pushed. Two days were spent in inspecting the works, which consist mainly of an enormous rubble

masonry dam 9,350 feet in length. When completed it will be 145 feet in maximum height. This dam is intended to furnish water for the city of Bombay. The rock for its construction is quarried at the dam site, but kunkar, for the production of cement, has to be brought long distances by rail or road cart. The aqueduct line, which carries the water to the city of Bombay, is partly in tunnel, partly in masonry conduit, partly in iron pipes. It has seven inverted siphons crossing drainage valleys, the greatest being 11½ miles in length.

On January 28 I left Bombay for Calcutta, a distance of about 1,200 miles. This trip was full of interest. During the early part of the first day the Thule Ghauts were ascended, the difficulties of construction being quite equal to those on the line between Poona and Bombay. Railway travel in India, while inferior in comforts to the United States, is still decidedly superior to European modes of making lengthy trips. The cars, like those on European railways, are short, and on only a few are bogie trucks used. These latter, however, are rapidly finding favor, and at no distant day will be universally employed on the Indian railways. Each compartment, of which there are two in every first and second class carriage, will hold from five to six persons. The seats are placed lengthwise of the train and are well cushioned. There is a hanging seat or bed suspended from the roof, similar to those seen in an American immigrant car. This can be lowered at night and used as a berth. Each passenger must carry his own bedding, which in that warm climate consists of nothing more than a blanket and a pillow, and spreading these on the seats or hanging beds he can pass a comfortable night on the road. In the center of the car, between the two compartments, is a small closet and toilet room. A table may be set up in the center of each compartment on which to spread lunches. Men and women are never permitted to travel in the same compartment. Good meal stations are placed at convenient intervals on all lines of railway, and ample time is given for eating.

The main portion of central India lying between Bombay and the Gangetan Plain is rather sparsely inhabited. The region is elevated and consists of uneven, rolling country, similar to that along the southern New Jersey coast or in the wooded districts of Missouri and Indiana. A dense growth of jungle, consisting of low trees, mesquite, teak, etc., with an undergrowth of tall, stiff jungle grass from 5 to 10 feet in height, covers the entire country. The streams draining this area are, during the dry season, but little rills, flowing through very broad, wide, sandy beds, that serve to indicate the enormous size these rivers attain during the flood season. There is little irrigation practiced in this region. In some sections moderate areas are irrigated from tanks of various sizes. The sloping hillsides are terraced, like those of Japan and China, by the construction of embankments. These produce level benches, where the flood water is held back sufficiently

long to enable it to soak into the ground. On these benches small crops of rice, garden truck, and grain are cultivated.

The River Jumna is first crossed and the Gangetan Plain entered at Allahabad, between which place and Calcutta the country is extremely level and fertile, having a strong resemblance to the broad, level prairies of the Mississippi Valley. Throughout this portion of the route fine fields of wheat, millet, barley, indigo, cotton, sugar cane, and poppy were passed in endless succession, while occasional groves of mangoes, cocoanut, and date palms relieve the prairie-like appearance of the country. The entire region is divided into innumerable small fields, each of a few acres, but no fences or houses were to be seen, though laborers dotted the fields. All live in villages, from which the laborers sometimes travel several miles to work.

I arrived in Calcutta on the morning of January 30, and called on Dr. W. King, the director of the geological survey of India, who gave me letters of introduction to some of the officials I was desirous of meeting. Mr. B. F. Bonham, American consul-general, treated me with the utmost courtesy and did everything in his power to aid me during my short stay. One day was spent at the office of the surveyor-general of India, Col. H. R. Thuillier, R. E., who kindly aided me in the examination of the methods of work of the topographic division and of the great trigonometric survey.

On the 31st I called on Col. J. M. McNeill, R. E., the secretary for government of the public works department of Bengal. With him I discussed the arrangement of my tour through his presidency, and from him I received letters of introduction to his various executive engineers. Colonel McNeill kindly telegraphed to Mr. R. B. Buckley, superintending engineer of the Soane canals, to arrange a hasty trip over his territory, and on the following day I reached Arrah, where I called upon Mr. Buckley. That day was spent in examining the maps and office records of the Soane canals, and on the following morning I set out on a tour of inspection. Mr. Buckley kindly placed at my disposal his canal steamer *Kodra*, on which I lived for three days, and Mr. Buckley also telephoned over the canal lines, arranging for various engineers to meet me and show me various points of interest.

I started early in the morning of February 2, and steamed up the canal against the current at the rate of about 8 miles an hour. The rate of travel was rather slow, owing to the velocity of the stream and to the great number of locks which had to be passed. At Arrah the canal is 86 feet wide at bottom, about 9 feet deep, and discharges about 2,000 second-feet of water. From there to the headwaters at Dehree, a distance of 65 miles, the Arrah branch follows the general direction of the Soane River on its western side, gradually increasing in width toward the head, where it is 180 feet wide at bottom, 9 feet deep, and discharges about 4,300 second-feet.

As Nasregunge, a large village midway between Arrah and Dehree,

I was met by Mr. Inglis, the executive engineer of the Arrah canal, who showed me the heads of some of the distributaries, the escapes, and also the mode of applying the water to the fields. I reached Dehree at 8 o'clock on the following morning. During the absence of the executive engineer in charge of the head works at Dehree, I was met by Mr. Williamson, the overseer of the shops at that point, who spent the day explaining the various works. These are of the most interesting and important nature, and consist of the great weir across the Soane River, 2¾ miles long and 14 feet in height, of the scouring sluices and regulators at the heads of the canals at each end, and of the general machine shops for the construction and repair of engines, dredges, and other metal works used on the canal system. The Soane River was then very low, scarcely discharging more water than was required to fill the main eastern and western canals. Thanks to this fact, I was enabled to watch the operations of the automatic sluice gates, which were lowered and raised for my inspection.

From Dehree I proceeded again by steamer down the Buxar branch of the main western canal, passing through immense fields of grains and vegetables, where but a few years before had been but a desert waste. One work of particular note passed was the Kao Nulla siphon aqueduct, whereby the canal is carried over the bed of the Kao Torrent and the latter in a semisiphon is passed under the aqueduct. A little farther on was a similar work by which the canal is carried in an aqueduct over the Thora Nulla. In the evening I arrived at the town of Buxar, where I met Mr. Horn, the executive engineer of the Buxar branch, and left the same night for Allahabad.

During the trip along the Soane canals many interesting scenes were noticed. Numerous canal boats loaded with grain or stone were passed. These were being taken to the railway or floated out on the Ganges River, whence they made the trip to Calcutta. The boats are peculiarly shaped, being higher at the stern than at the bow, varying from 15 to 25 feet in length, and having a width of about 10 feet. In the center is erected a pole, perhaps 12 feet in height, to which are attached numerous light strings, and each of these is drawn by a native on the towpath. On these canals it is not unusual to see ten or more men towing one boat.

The important roads cross the canal by means of well-constructed masonry or iron bridges. A peculiar accident has occurred to many of the masonry bridges, as the pressure of the earth embankments behind the abutments causes them to act as retaining walls. The pressure has in several cases caused the arches to spring upward at the center or key, leaving a slight crack on top. These bridges have been constructed strong enough to perform their duties as bridges, but are not sufficiently strong to act as retaining walls.

The smaller roads and footpaths terminate at the canal banks, where catamaran-shaped ferryboats are used to cross the canal. These

boats are unique in construction. Each pontoon is composed of rive sheet iron and is 2 feet wide by 2 feet deep and 15 feet in leng Between the two is supported a wooden deck 6 feet wide, sufficien large to carry the ordinary two-wheeled bullock cart with its te A chain is laid from one bank of the canal to the other, long enou to rest on the bottom of the canal, so as not to impede traffic, and pa ing through a ring on the deck of the ferryboat. By pulling on t chain the occupants are enabled to draw the boat across the cana

The canal banks are lined throughout with plantations of trees, property of the canal government. These are cut and sold as n seem desirable to the canal officers, all trees thus removed be replaced by young growths. Among the more usual trees are sissoo, somewhat like the teak in general character, and used in construction of furniture, carts, etc., the sal, also used for furnit and fuel, some mangoes, and some mesquite.

Owing to the low velocity, about 3 feet per second, which it is n essary to give the navigable branches, considerable deposits of accumulate near their heads, and lower down, where the wate clearer, reeds and rushes line the banks well out toward the middl the stream. Large steam dredges are kept at work on the upper li of the Soane canals, giving them much the appearance of the S Canal. These dredges have mostly been constructed at the shop Dehree, and are of iron throughout, as are also the scows. La steam passenger boats ply on the main canals, stopping at the vari villages lining their banks and terminating their runs at the railw These boats are crowded with people, which indicates a profita passenger traffic.

Among the most interesting scenes observed were the enorm crowds of pilgrims, afoot, on camels, or on bullocks. These pilgr make journeys between distant shrines, often occupying six mon in the longer trips. Each devotee carries a pole across his back, f the ends of which are swung the few necessaries of food and cloth

The locks along the canal are substantially constructed of b masonry, sometimes singly and sometimes in pairs, and averag their lift from 7 to 12 feet. These locks are sufficiently long and w to accommodate the big passenger steamers. Beside and around locks is always constructed a waste weir and channel through wh the greater part of the discharge of the canal used in irrigation not required in operating the lock is passed. In this channel is essarily a high fall with a drop equal to that of the lock. This is built of the most substantial masonry in order to withstand the caused by the great body of water passing over it.

On February 5 I arrived at Allahabad, the capital of the North Provinces and Oudh, where, during the absence of the chief engi and secretary for government, Col. G. T. Skipworth, R. E., I was w courteously treated by Mr. H. W. Conduitt, the office assistant.

gave me some official reports and letters to engineers in the northwest and arranged for a visit to the Betwa, Ganges, and other canals by writing to the executive engineers in charge, informing them of my approaching visit and requesting them to render such assistance as might be required. On the same day I proceeded to Orai, where I was met by Mr. W. P. Vonder Horst, the executive engineer of the Betwa canal. The 6th was spent in examining the office records and maps and making such notes and tracings as were deemed necessary. On the same evening we left by rail for Chirgaon, whence a short tonga ride took us to Paricha, the head of the Betwa canal and the great Betwa reservoir.

The Betwa reservoir is constructed in the channel of the Betwa River where it emerges from the Northern Ghauts. The weir is located in a rather wide part of the river bed, crossing the stream in an irregular line, abutting in one place on a large island and at another on a broad rock in the middle of the river. The total length of this weir, including the islands on which it abuts, is about 4,300 feet, and its greatest height in the middle of the channel is 60 feet. The entire dam acts as an overflow weir, in order to give sufficient wasteway to the enormous flood of 750,000 second-feet which may pass over it. Such a flood would bank 17 feet deep over the crest of the weir. In order to withstand the shock of this body of falling water two small subsidiary weirs have been constructed in the channel below the deepest portions of the weir, thus giving a water cushion on which the maximum height of the overfall is 21½ feet. The net storage capacity of this reservoir available for irrigation purposes is nearly 37,000 acre-feet.

The canal system heading immediately above the dam controls an area of about 950,000 acres, of which about 400,000 is excellent arable land. The balance is very poor and barren. This area of irrigable land is included between the Betwa, Pahug, and Jumna rivers, and at present about 135,000 acres are irrigated by the canal system. The flushing sluices on the end of the weir adjacent to the canal head and the regulators at the canal head are of great interest, owing to the pressure of nearly 60 feet under which the gates are operated.

From Paricha I proceeded by rail to Agra, and on February 9 went to Narora, where are located the head works of the Lower Ganges canal. In order to reach Narora it was necessary to go by rail to Aligarh, where a couple of hours were agreeably spent. From Aligarh I went by rail to Rajghat, which station was reached late in the evening. There, thanks to the thoughtfulness of Mr. E. A. Carswell, the executive engineer in charge of the Narora works, I was met by a hand car or trolley, in which I was pushed by natives 5 miles to the bungalow at Narora, where the following night and day were spent. I was received by Mr. Carswell with the same hospitality that had been accorded me by all the other officials with whom I had come in con-

tact. The larger part of that evening and the next day were spent in examining the office reports and maps and examining the head-works and the river training system of the Lower Ganges canal. These head-works consist of a great weir 4,135 feet in total length, 3,700 feet of which are composed of an overfall weir 14 feet in height above the foundation, 315 feet consisting of sluice gates adjacent to the head of the canal. The head of the canal adjacent to the end of the weir consisted of 26 regulating gates, each 7½ by 11½ feet in the clear. The maximum flood coming down the Ganges which may pass over this weir may be as great as 230,000 second-feet.

The river training works are interesting and extensive. They are necessitated by the low character of the river bottom, in which the canal is constructed for some miles before its diversion line gets out of the bottom and reaches the summit of the bluff. Where these bottom lands are traversed the river is apt to change its channel, and if not controlled would cut its banks, thus destroying the canal. The regulating works are carried for 4 miles above the head of the canal and 15 miles below it, and consist of long earthen embankments or groynes, which jut straight out into the river channel at right angles to its course and are protected on their ends by rock paving and rock noses. Sixteen miles below the Narora weir the Lower Ganges canal crosses the great Kali Nadi Torrent, which in time of floods becomes an enormous river. The canal is carried across this torrent on an aqueduct which provides water way for a flood of 130,000 second-feet. The channel of the canal on the top of the aqueduct is 130 feet wide and 7 feet deep. Previous to 1885 there was in this place a short aqueduct calculated to pass a flood of 30,000 second-feet; but in that year it was destroyed by an unprecedented flood of nearly 130,000 second-feet, and has since been entirely remodeled and reconstructed.

On February 12 I left Narora for Lahore, the capital of the province of Punjab. In the absence of Col. F. J. Home, R. E., the chief engineer for irrigation in the Punjab, I presented my letters of introduction to Mr Cockhorn, the office assistant, who had been instructed by Colonel Home, in anticipation of my arrival, to furnish what aid he could. In the Punjab I was less fortunate than elsewhere. The works of that region are among the greatest and most interesting in India. I reached there in the midst of the busiest part of the field season. Most of the engineers were far out of reach of railways or other convenient modes of travel, in charge of the construction of works, and as time was limited it was impossible to go far out of the way to meet them. Accordingly, I decided not to visit the works of the Western Jumna nor the Bari Doab canals, but to devote the remaining time to a thorough inspection of the Sirhind canals, which are the most modern and perhaps the most interesting of any of the canals of India.

I at once proceeded to Amrister in hope of meeting Major Ottley,

R. E., the supervising engineer, from whom I expected information and assistance in the trip. Here, again, I was disappointed, and found no one who could give assistance or advice as how to visit them best. Accordingly I decided to go to Ludhiana, the nearest railway point to the canal. I reached there on February 14 and called on Mr. J. Dempster, executive engineer in charge of the Sirhind canals. I did not receive much encouragement from Mr. Dempster, as he said that owing to not having been previously advised of the trip and the shortness of the time it would be nearly impossible to arrange conveniently to show me the canals. From Ludhiana to Rupar, where the head-works of the canal are, is a distance of about 60 miles, and to make this trip it would be necessary to engage an elephant and to procure the necessary traveling outfit. As I did not know where to find these, and Mr. Dempster was apparently too busy to aid in the search, I reluctantly abandoned the journey, and on the same day left by train to visit the Ganges canal.

Next morning, February 15, I reached Roorkee, where I found that Mr. M. King, executive engineer, had made elaborate preparations for the trip over the line of the canal. I also found Col. G. T. Skipworth, R. E., chief engineer of the Northwest Provinces and secretary to government, and Mr. W. J. Wilson, his assistant secretary. They had made preparations for the annual inspection of the lines of the canal, but as they would not be prepared to set out on their trip for a few days, Mr. King had arranged to take me to the head-works and return to Roorkee in time to accompany the inspecting party. A portion of the 15th was spent in examining the office records and maps, and early on the following morning Mr. King and I set out on a tonga drive along the banks of the canal bound for Hardwar, where are situated the head-works. Owing to the heat, though the distance was but 20 miles, two relays of horses had been sent out to hasten the journey. Two heavy bullock carts laden with camp equipage, etc., and an elephant which would be required in making journeys away from beaten roads, had also been previously forwarded to Hardwar. In the course of the drive along the canal banks we had an excellent opportunity for investigating the level crossing of the Rutmoo Torrent at Dhanowri. We also examined the great aqueduct by which the Ganges canal is carried across the Solani Valley and the superpassages which conduct the waters of the Puthri and Ranipur torrents over the Ganges canal. These works were also examined on the return trip to Roorkee, when I was enabled to observe other points of interest that had escaped notice on the first inspection.

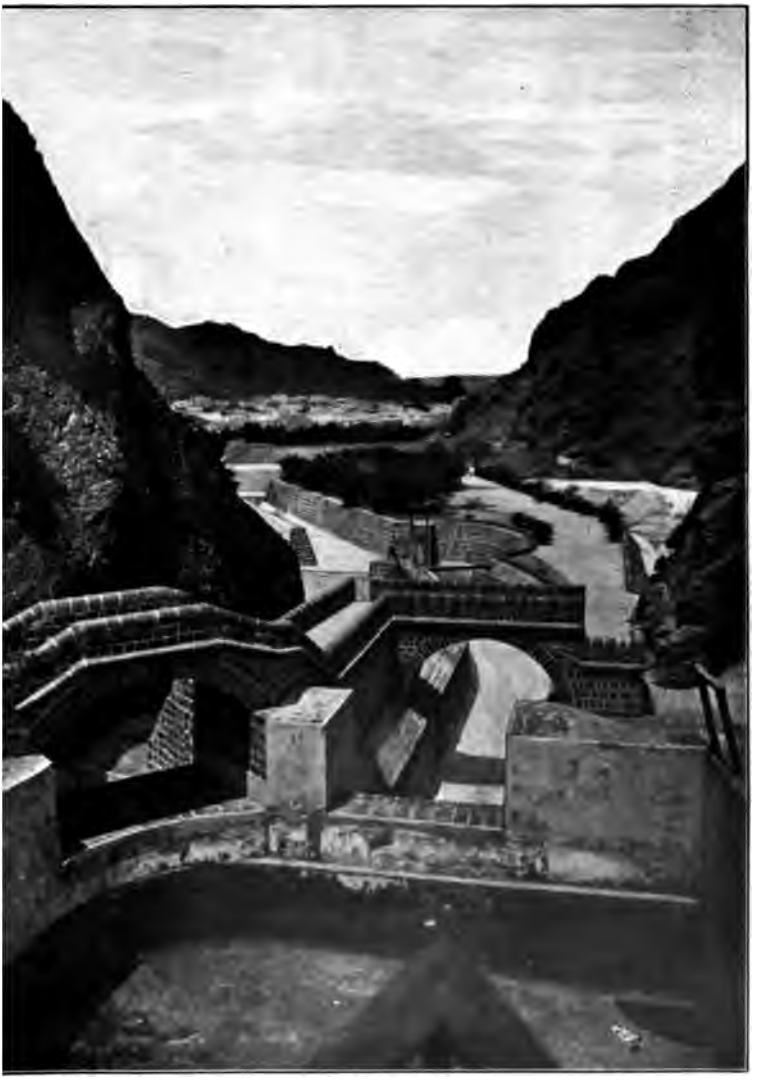
We spent the night at Hardwar and on the following day set out on the elephant to examine the various river training and regulating works, whereby the greater part of the water of the Ganges River is guided into the Hardwar channel, from which it is diverted into the canal. These training and regulating works extend for a distance of

several miles above Hardwar and are unique from the fact that the supply of water being at all times abundant for the demands of the canal, no permanent dam has been thrown across the river. The bed of the river is here broken up into several channels and is very wide, but by means of a row of three temporary dams constructed of bowlders the majority of the water is turned into the Hardwar channel. These temporary dams, it has been found, can be more cheaply reconstructed annually after their destruction by the regular floods, than a great permanent weir could be built across the entire channel. Above the temporary bowlder dams a permanent masonry wall has been constructed on one minor channel besides a series of permanent bowlder embankments and bars, the latter to prevent the retrogression of grades. Groins and other training works so confine the main body of water to the Hardwar channel that during times of greatest flood, when all of these works are submerged, little or no damage is done to the permanency of this channel. At Myapur, the head of the Ganges canal, below the training works, a permanent weir with the usual scouring sluices has been thrown across the Hardwár channel, thus training the water into the regulator at the head of the canal.

On the following morning we continued our inspection of the head-works and in the afternoon returned to Roorkee. The 18th was spent at Roorkee in a visit to the Thomason College of Civil Engineering, where Colonel Brandreth, the president, kindly showed me over the building and furnished numerous valuable reports and other information.

On February 20 I reached Okhla, near Delhi, at which place are situated the head-works of the Agra canal. Here, thanks to the kindness of Colonel Crofton, superintending engineer, who had written from Roorkee of the intended visit, I was met by Mr. C. G. Palmer, the executive engineer of the Agra canal, with whom I visited the works under his charge. The head-works of this canal consist of a low weir 10 feet in height and 2,573 feet in length from the right bank, the left wing resting on an island in the middle of the river. Wings and heavy earth embankments, 20 feet wide on top, are carried across the island and the east channel and thence up the left bank to the railway bridge at Delhi.

This canal receives its water supply from the Jumna River, which, however, does not at all times carry sufficient water to fill it. Its supply is accordingly augmented by means of a cut from the Hindun River, which empties the water of that stream into the Jumna above the diversion weir. In the weir there is the usual set of scouring sluices at the end adjacent to the canal head and the customary regulating gates and lock for navigation purposes at the canal entrance. Like the Ganges River at Narora, the Jumna here requires the construction of great river training works similar in their general character to those on the Lower Ganges, but in order to throw the greater



ADEN TANKS, ARABIA.

rtion of the water toward the right bank of the river, where the nal head is, alligator groins have been run at right angles to the ıe of the weir, by means of which the water is trained in the desired rection.

After examing the office records and maps at Okhla, Mr. Palmer ıd I made a trip by tonga down the line of the canal to examine some the works of interest. We passed several inlets by which the drainge of small streams heading in the hills to the south is admitted to ıe canal. The water enters by stone culverts, and the core of the ınal embankment at these places is usually constructed of rubble asonry. These inlets are generally controlled from a gate tower. ear the Ali Torrent the canal banks are protected on the upper side y a long earthen dam, forming a storage reservoir which catches the rainage of several small streams from the hills and passes this through n outlet or spillway into a superpassage of sheet iron carried over the ınal. The water retained in the reservoir is allowed to settle, and hen clear of silt is admitted into the canal, but in time of floods the ıperabundant discharge is carried over the spillway previously menoned and discharged into the Jumna. Many hundreds of small tanks ave been constructed all through this region, and one very large one ı now under construction on the Surwa River about 15 miles above aroda.

Among the most interesting sights from a scientific point of view to e seen in India are the ancient astronomical observatories erected by ıe old Arab astronomers at Delhi and Jeypur. At the latter place I ad an opportunity to examine carefully the observatory of the Shah ehan, which covers a couple of acres of ground and is surrounded by high stone wall. Within this inclosure are constructed many unique ıasonry instruments with which were conducted the observations of ıe ancient astronomer.

On March 3 I reached Bombay, and a few days afterwards left for ome.

At Aden I stopped a day, thus giving sufficient time to examine ıe strange old reservoirs (Pl. II), constructed in a gully above that ıwn, which supply it with water. It is only once in several years ıat a sufficient rainfall occurs in this arid region to fill the tanks. here are several of them, one above the other far up the gully, and was my good fortune to be there a few days after the occurrence of ıe first storm that had filled them in three years. They are most ırefully constructed, lined throughout with hydraulic cement, thus reventing any leakage through their rock bottoms, and are closed y substantial dams with wasteways and masonry conduits leading om one to the other, so that the least possible amount of water will e lost by absorption. The total storage capacity of these tanks is bout 12,000,000 gallons.

From Aden I proceeded direct to Suez, where I took the train for

Cairo, arriving there on March 18. Here I called upon the American consul-general, Mr. Eugene Schuyler, who informed me how best to see the irrigation works in the immediate vicinity. By him I was introduced to Col. Sir Scott Moncrieff, the minister of public works for the government of Egypt, from whom valuable information and numerous reports relative to the irrigation works of that country were obtained. The next day the Barrage du Nil was visited, it being readily reached by a railway trip from Cairo occupying about an hour. Two other trips to the Barrage were made, during which ample opportunity was had to examine the works. Construction was being rapidly pushed, and there were probably 6,000 workmen employed on them.

A few days later I proceeded to Brindisi, Italy, thence to Rome, where I arrived March 30. In Rome, thanks to the kindness of the American minister, the Hon. A. G. Porter, I called upon the minister of finance, under whose direction are the irrigation works of Italy. From him I received a letter to Signor Carlo Sospizio, the director of the Cavour canal at Turin, and on the following day I reached Turin. Signor Sospizio was very courteous, and arranged to have one of his subengineers meet me the following day at Chivasso, where the headworks of the Cavour canal are, and show me over them.

On April 2 I was met at Chivasso by Signor Canavotte Oreste, an assistant engineer. With him the following two days were spent in an inspection of the line of the Cavour canal as far as the inverted siphon crossing the River Sesia. The trip was made from Chivasso in a carriage along the canal banks as far as the aqueduct crossing the River Dora Baltea, below Saluggia. From this point the carriage was sent around the road to Saluggia and we examined the canal and aqueduct on foot, rejoining the carriage at Saluggia.

The weir across the River Po at the head of the Cavour canal is a temporary one, constructed of brush and rocks, and is not over 5 feet in height. This weir has to be annually repaired, but this is less expensive than the construction of a permanent one would be. When the River Po is low, and does not discharge sufficient water for the wants of the canal, additional water is supplied by the subsidiary Canal Farini, while the Canal Rotto adds some of the water of the Dora Baltea to it.

Above Saluggia, near Cigliano, is an interesting arrangement for lifting the water from a low- to a high-level canal. This consists of four levels of canals. Between the two lower ones is placed an extensive pumping plant, operated by turbines which receive their water from the upper of the two lower canals and tail into the lower canal, whence the water is distributed to low-lying fields. The lower of the two upper canals supplies water by means of an immense wrought-iron pipe, 3 feet in diameter, with a head of about 66 feet, to the

pumps below, and these force it, through another pipe of the same dimensions, a total height of 140 feet, to the high-level canal, whence it is distributed to the upper fields.

From Saluggia we proceeded by rail to Santhia, near where the Canal Cigliano passes over the Ivrea canal and at the same time supplies it with water. The night was spent in Vercelli, and in the morning we proceeded to Greggio, where the Cavour canal passes under the River Sesia in a great siphon nearly 800 feet in length, which carries the entire capacity of the canal. This system consists of four channels or conduits constructed of masonry, oval in shape, the inside diameters of which are 9 by 15 feet.

On the following day I proceeded to Milan, thence over the celebrated St. Gotthard route through Switzerland to Paris, where I arrived on April 6. In Paris, through the courtesy of the minister of public works, I received a letter to M. Caméré, engineer in chief of bridges and roads, located at Vernon, with whom I examined the various barrages which regulate the navigation of the Seine. At Paris the examination of irrigation works came to an end, and I proceeded thence direct to the United States.

LIST OF WORKS ON INDIAN IRRIGATION.

In the following list are arranged alphabetically by authors the titles of works which were referred to in the preparation of this report. This list does not pretend to be a complete list of works and pamphlets published on Indian irrigation:

Anderson, C. E. Damage to Works of Agra Canal by Floods of September, 1875, to February, 1877. Allahabad, India, 1878.

Anderson, Col. J. C. Irrigation in Madras Presidency. Professional Papers, second series, No. 253. Roorkee, India.

Ashhurst, F. H. Reconstruction of Bhin Tal Dam, Kumaon. Proceedings Institution Civil Engineers, vol. 75, pp. 202–210. London, 1884.

Bellais, E. S. Inundation Canals in the Punjab. Proceedings Institution Civil Engineers, vol. 89, p. 521. London, 1887.

Beresford, J. S. Proposed Standard Designs for Masonry Outlets. Nanai Tal, India, June, 1882.

——— Duty of Water. Memoranda on Irrigation. Professional Papers, second series, No. 212. Roorkee, India.

Binnie, A. R. Nagpur Water Works. Proceedings Institution Civil Engineers, vol. 39, pp. 1–61. London, 1875.

Buckley, Robert B. Irrigation Works in India and Egypt. E. & F. N. Spon. London, 1893.

——— Keeping Irrigation Canals Clear of Silt. Proceedings Institution Civil Engineers, vol. 58, pp. 278–280. London, 1879.

——— Statistical Review Irrigation Works of India. Calcutta, India, 1889.

——— Movable Dams in Indian Weirs. Proceedings Institution Civil Engineers, vol. 60, pp. 43–55. London, 1880.

Burke, C. T. The Ashti Tank. Proceedings Institution Civil Engineers, vol. 76, pp. 288–316. London, 1883.

Cautley, Col. Sir Proby T. Report on the Ganges Canal Works, 3 volumes and atlas. London, 1860.
——— A Disquisition on the Heads of the Ganges and Jumna Canals. London, 1864.
Conybeare, H. Tanks in Rajpootana. Proceedings Institution Civil Engineers, vol. 17, p. 569. London.
Craig, James. Maximum Flood Discharges from Catchment Areas. Proceedings Institution Civil Engineers, vol. 80, pp. 201–220. London, 1885.
Crofton, Capt. J. Report on the Ganges Canal, 3 volumes. Public Works Department. Calcutta, India, 1865.
Davidson, Prof. George. Irrigation and Reclamation of Land for Agricultural Purposes in India, Egypt, Italy, etc. Executive Document No. 94, United States Senate, Forty-fourth Congress. Washington, D. C., 1875.
Dickens, Lieut. Col. C. H. Projects of Canals of Irrigation from the River Soane. Government Printing Office. Calcutta, India, 1861.
Encyclopaedia Britannica. India. London.
——— Irrigation. London.
Famine Commission Report, Appendix I. Condition of Country and People of India. London, 1881.
——— Part II. Measures of Protection and Prevention. London, 1886.
——— Appendix III. Report of Country and People. London.
——— Appendix V. Irrigation as a Protection Against Famine. London, 1881.
Forbes, Col. J. G. Revised Estimates of Agra Canal. Simla, India, 1885.
Forrest, R. E. Irrigation and Drainage in the Dehra Dun. Professional Papers, No. 5. Roorkee, India.
Galton, Capt. Douglass. Sanitary Progress in India. Journal Society of Arts, No. 1223. London, 1876.
Gordon, W. B. Notes on Well Sinking at Nadrai Aqueduct. Allahabad, India, 1888.
Government, Northwest Provinces. Canal Act VIII, 1873. Allahabad, India.
——— Northwest Provinces. Land Acquisition Act. Allahabad, India.
——— Canal Act VII, 1879. Bombay, India.
——— Book of Circulars for Guidance of Officers, Irrigation Branch Public Works Department. Calcutta, India.
Greathed, Col. W. H. Irrigation in Northern India. Proceedings Institution Civil Engineers, vol. 35, pp. 139–185. London, 1872–73.
Greaves, C. Evaporation and Percolation. Proceedings Institution Civil Engineers, vol. 45, pp. 19–105. London, 1876.
Harlacher, Prof. A. R. Current Meter. Proceedings Institution Civil Engineers, vol. 67, pp. 358–368. London, 1882.
Hart, J. H. E. Mutha Canals. Bombay, India, 1879.
Haywood, Captain. Practical Gauging of Rivers. Professional Papers, vol. 7. Roorkee, India, 1870.
Hilgard, E. W. Alkali Lands. College of Agriculture, University of California. Appendix 7. Sacramento, Cal., 1886.
Home, Lieut. F. Tank Irrigation in Ajmere and Mairwara. Professional Papers, No. 229. Roorkee, India.
Jackson, Lowis D'A. Hydraulic Works. London, 1885.
LeMesurier, J. Slips in Earthen Embankments of Tank in Bombay Presidency. Bombay, India.
Levinge, H. C. Soane Canal. Professional Papers, vol. 7. Roorkee, India, 1870.
Madras engineers, Professional Papers, 4 volumes. Madras, India, 1856.
Malet, H. P. Indian Irrigation. Geographical Magazine, vol. 5, pp. 232. London.

Markham, C. R. Irrigation in Southern India. Geographical Magazine, vol. 1, 1876, pp. 329–332. London.

——— Irrigation in Southern India. Geographical Magazine, vol. 4, 1877, pp. 279–280. London.

Medley, Lieut. Col. J. G. Manual of Irrigation Works. Thomason Civil Engineering College. Roorkee, India, 1873.

——— India and Indian Engineering. E. and F. N. Spon. London, 1873.

Molesworth, Guilford. Village Tanks, Ceylon. Professional Papers, vol. 6. Roorkee, India, 1889.

Moncrieff, Lieut. Scott. Irrigation in Southern Europe. E. and F. N. Spon. London, 1868.

Mullins, Captain. Lucknow and Mason Reservoirs. Professional Papers, vol. 6. Roorkee, India, 1869.

Mullins, Lieut. Gen. J. Irrigation Manual. E. and F. Spon. New York and London, 1890.

Norton, C. E. Irrigation in India. North American Review, vol. 77, p. 439. N. Y.

O'Connell, Lieut. Col. P. P. G. Flood Discharges of Rivers. Professional Papers, vol. 7. Roorkee, 1870.

Palmer, E. C. Irrigation Experiments. Professional Papers, second series, No. 35. Roorkee, India.

Playfair, Lieut. Col. J. W. Professional Papers, No. 217. Roorkee, India.

Public Works Department, Bengal Annual Revenue Reports. Calcutta, India.

——— Betwa Canal in Bundelhand. Allahabad, India, 1874.

——— Correspondence relating to Nira Canal. Bombay, India. 1877–1881.

——— Annual Irrigation Revenue Reports. Bombay, India, 1889.

——— Lower Ganges Canal Project. Allahabad, India. 4 vols. 1874–1876.

——— Madras Annual Irrigation Revenue Reports. Madras, India.

——— Northwest Provinces. Annual Irrigation Revenue Reports. Roorkee, India.

——— Northwest Provinces. Revised Estimates of Agra Canal. Sind, India, 1887.

——— Punjab Annual Irrigation Revenue Reports. Lahore, India.

——— Sind Annual Irrigation Revenue Reports.

Records Government of India, Betwa Canal Project in Northwest Provinces, No. 232. Calcutta, India, 1887.

——— Failure of the Kali Nadi Aqueduct. Lower Ganges Canal, No. 240. Calcutta, 1888.

——— Sidhnai Canal Project in the Punjab, No. 248. Calcutta, India, 1888.

——— Zhara Karez Irrigation Scheme. Beluchistan, No. 231. Calcutta, India, 1887.

Sanky, Maj. R. H. Irrigation in Mysore. Professional Papers, Nos. 141 and 150. Roorkee, India.

Smith, Capt. R. Baird. Italian Irrigation. Wm. Blackwood and Sons. London, 1855.

——— Irrigation in Madras, India. London, 1856.

Statesman, India, 1890.

Thornton, W. T. Irrigation a Preventative of India Famine. Journal Soc. Arts, No. 1319. London, 1878.

Tullock, Maj. Hector. History of Bombay Water Supply. Professional Papers, Second series, No. 77. Roorkee, India.

Torricelli, G. Notes on More Important Features of Reservoirs for Irrigation. Proceedings Institution Civil Engineers, vol 84, pp. 483–485. London.

Vernon-Harcourt, T. F. Fixed and Movable Weirs. Proceedings Institution Civil Engineers, vol. 60, pp. 24–42. London, 1880.

Victor, H. Notes on Irrigation in Bombay Presidency. Professional Papers, No. 181. Roorkee, India.

Walker, J. P. H. Mahanuddy Anicut. Professional Papers, vol. 7. Roorkee, India, 1870.

Western, Major. Rules for Rajbuha Estimates. Punjab, India.

Whiting, J. E. The Nira Canal. Proceedings Institution Civil Engineers, vol. 77, pp. 422–423. London.

Wilson, Allen. Irrigation in India. Proceedings Institution Civil Engineers, vol. 27, p. 454. London.

Wilson and Logan. Irrigation in India and Spain. Proceedings Institution Civil Engineers. Excerpts, 1867, 1868, 1869. London.

CHAPTER I.

FINANCE AND STATISTICS.

VALUE AND NECESSITY OF IRRIGATION.

n view of the interest in the subject of irrigation which has been ently developed in this country, it will be well to observe what ıefits have been derived financially and otherwise from the irrigation ·ks that have been in active operation in India during the last cen- y, and also to note what Indian and English statesmen and engi- ·rs have to say on the subject of the extension of irrigation in India. :ause of the similarities of the countries, climates, and the condi- ıs under which irrigation works are operated in America and lia, some useful lessons may be drawn from these comparisons. It ı already been shown that the conditions of the utilization of the ters of irrigation works are quite similar in the two countries, and t the autumn crop in India is cultivated under circumstances ıost identical with those under which our ordinary summer crops grown in the arid regions.

'he Indian financier divides the irrigation works into two great sses, called major and minor works. Major works are generally se of more importance from an engineering point of view, and have n in some cases almost entirely constructed by the British Govern- ıt, while the minor works are of smaller pretensions and in many es modifications or improvements of existing ancient irrigation tems. The portion of the major works that are constructed from ital provided from the general revenues of India are styled "pro- ·ive works." "Productive works" are usually constructed from ital which has been borrowed, and it is expected that a sufficient fit will be realized from their operation to pay interest on the bor- ed money. Many minor works are also productive works. In eral, protective works are constructed as a protection against ines, and they act in the amelioration of these in two ways. First, ·ı are constructed during famine times to give employment to the ple and furnish them money and food for their sustenance, and ınd, after their construction they are expected to furnish sufficient er for irrigation purposes to render them a protection against ıre droughts and the resulting famines. The majority of these ine protective works consist of storage reservoirs constructed in more arid portions of India.

The reason for the success of the greater productive works of northern India is twofold. First, these works are constructed in a country similar to that of the western United States, so barren and devoid of water that nobody could live there or produce crops of any sort until canals had been dug and water provided for irrigation. Accordingly, all those who immigrated to the neighborhood of these canals were at once compelled to use and pay for the water, otherwise they would have been unable to raise crops. It is owing to the fact that these works have been able to do their full duty and the total amount of water furnished by them has been in constant demand that they have earned interest. On the contrary, the protective works, which have usually proved financial failures, have been built in regions where in ordinary years the precipitation has been sufficient to produce good crops, but where during occasional years the crops suffer from lack of water, and it is then only that the irrigation works are called upon. Such works being only utilized occasionally, produce only moderate returns during occasional years. Were these works constructed in a less inhabited region and in one lacking sufficient precipitation to raise crops, they would doubtless then do constant duty, and it might reasonably be expected that they would become productive works. In some few cases, such as those of the Sidhnai canal in the Punjab and the Betwa canal and reservoir in the Northwest provinces, works originally constructed as protective works have received such a constant demand for their waters that they are now productive, returning moderate interest on the capital.

Anywhere in our arid West where irrigation works may be constructed it is reasonable to suppose, judging from analogy, that when a sufficient population settles below them, these works will be called upon to furnish all the water they can provide, and if properly and carefully planned and estimated for should return fair interest on the original outlay. Only semihumid regions, such as western Kansas, the Dakotas, Nebraska, and Oklahoma, have been subjected to famines. These occur every few years, and are the results of the country having been settled during periods of fair rainfall. Following these good years came a season or two of minimum rainfall when the crops were parched. It is only because of the increased transportation facilities in our West and the extensive charities undertaken by the Government and people that settlers in that portion of our country have been saved from famine. It is in such regions as those in India that the Government has devoted the most time, attention, and money for the construction of irrigation works as a means of protection against such losses, and convincing arguments have been brought to prove that money expended in such protective works is saved to the Government.

The high price paid for labor as compared with that in India is the argument generally used to prove that similar profitable returns from irrigation enterprises in this country can not necessarily be expected,

as the cost of construction here would be proportionately so much greater as to demand a higher return from the use of water in order to pay a corresponding rate of interest. It is not improbable that with the increased amount of work done by an American laborer as compared with that of a Hindoo coolie, and with the aid of many mechanical devices, the discrepancy in cost is not so great. Moreover, returns derived from irrigation works in the two countries are more nearly equalized from the fact that we can impose a higher tax for the use of water than it is possible to demand of the poor farmers in India, where from 2 to 5 acres support a large family. The apparent low cost of Indian labor is at first glance against this argument. Men, women, and children are engaged alike in the construction of all works. As common laborers women and children receive about 4 cents per day, and men from 8 to 10 cents. Skilled masons and machinists receive from 18 to 22 cents per day, and carpenters and blacksmiths nearly the same.

In the interior towns of the Bombay Presidency contract prices are about as follows: At the Bhatgur dam uncoursed rubble masonry costs $1.75 per cubic yard, while at the Tansa dam it costs $2.50 per yard. In the Northwest Provinces earth excavations in deep canal cuts cost 6⅔ cents per cubic yard, while surface excavation costs 2½ cents. In the Punjab, according to the revenue reports, water in the canals yields a return of from 70 cents to $1.25 per second-foot, while the water rate charged per acre irrigated was from 70 cents to $1.15. In Bombay, according to the revenue report of 1889, the water rate derived was $1.15 per acre irrigated, and ranged from 35 cents to $3, the latter figure being abnormal and paid for the irrigation of sugar-cane crops, which require an enormous amount of water in their cultivation. Against these prices we are able to obtain in the central arid regions of America a revenue of from $1.50 to $3 per acre, which is equivalent for a duty of 80 acres per second-foot to from $120 to $240 per second-foot utilized. In California and other portions of the country where water is scarce and the crops valuable the rate is usually many times higher than the above.

In the province of Sind in the Indus Valley, including the southern Punjab, there is an enormous and thirsty waste of sandy desert where the annual precipitation is always below 10 inches, even falling as low as 3 or 4 inches. There nothing can be grown without the aid of irrigation, and the entire area under cultivation and the population supported thereby are entirely dependent on irrigation. The works in that region are chiefly inundation canals with a few perennial canals mostly taken from the Indus River. In the Sind alone over 3,000,000 acres are under cultivation, and yield an annual revenue of about $3,700,000.

In Bombay and the Northwest Provinces nearly double the population is now sustained that was supported previous to the introduction of modern irrigation works. According to Col. Baird Smith, the whole

of the region irrigated by the Eastern Jumna canal would have been devastated by the famine of 1837–38 without the aid of the irrigation which that canal afforded. With its aid the population was comfortably supported and the gross revenue derived from the use of the water was $2,445,000, of which the Government received a yearly net income of $250,000, and this shortly after the completion of the work. In the same year the united Eastern and Western Jumna canals were estimated to have saved property to the value of $10,000,000, and as a result of this showing the British Government shortly afterwards began the construction of the great Ganges canal and other similar works, From the report of Major Baker, R. E., it appears from actual measurements made on the Western Jumna canal in 1838 that the gross value of crops on lands irrigated by that canal was $7,500,000, of which $750,000 was paid to the Government as land and water rent; the remainder aided to feed and support the inhabitants of 500 villages during a period of devastating famine. Without irrigation this land would, during that drought, have been totally unproductive.

As an indication of the increased revenue derived from the use of water and the capability of the soil to pay that increase, it appears that in the presidency of Madras the rate of assessment in the tank region is about $2.30 per acre on irrigated land, as against 55 cents per acre on land not irrigated. It is difficult to show in a satisfactory manner what has been the actual result of the irrigation works in India as financial undertakings. The figures given convey little idea of the actual benefit derived from the canals, as much of this is collected as the land tax, which forms nearly half the total revenue of the Indian Government.

Another difficulty in reviewing the financial results of Indian irrigation works is found in the fact that in several cases capital shown by the Government accounts does not include the value of the old native works, upon which the British undertakings were founded. Recognizing these difficulties, Major-General Dickens presented to the select committee on public works a statement of which the following is a summary, which was given as the nearest approximate to the truth that could be obtained. This statement was for the year 1875–76 only, and no allowance was made for the value of the old native works, which General Dickens stated did not exceed $2,500,000. The total expenditure to date was $77,500,000; the total receipts were $6,150,000, and the working expenses were $2,000,000. This shows that the irrigation works of India, taken altogether, paid at that time a revenue, direct and indirect, of 5½ per cent to the state. This includes some works which were only partially in operation. General Dickens anticipated that when in full operation they would eventually pay 6 to 7 per cent.

As an indication of the time which must necessarily expire after a canal work is opened and before it is doing its full duty and return-

ing its full revenue, the great Ganges canal was fourteen years in operation before it paid 4 per cent on its simple capital, and Colonel Crofton, the late inspector-general of irrigation in India, appears to think that ten years is by no means an unreasonable time to elapse after an irrigation work has been put in operation before it can pay interest on its cost. Gen. R. Strachey in 1865 gave it as his opinion that it was not likely that even 5 per cent would be realized in ten years on the capital stock on any but the smallest irrigation works, while Col. Baird Smith took it for granted, in reporting on the proposed Soane canal, that the works would not be self-supporting for sixteen years after they had been opened for irrigation.

The following quotations are from the reports of the select commission appointed in 1888 by the British Government to report on measures of protection from and prevention of famine. This report bears great weight, owing to the high character of the members of the commission, both as engineers and men of experience in the construction and management of irrigation works and as statesmen of broad views, whose integrity can not be doubted. This commission consisted of Gen. Richard Strachey, James Caird, H. S. Cunningham, H. E. Sullivan, and J. P. Peile. Their remarks relative to the value of irrigation works were as follows:

It is not only in years of drought and as a protection against famine that irrigation works are of value. In seasons of average rainfall they are of great service and a source of great wealth, giving certainty to all agricultural operations, increasing the outturn per acre of the crops, and enabling more valuable descriptions of crops to be grown. The following instances may be quoted from the mass of evidence before the commission: The outlay on completed canals in the Punjab up to the close of 1877–78 had been $11,300,000. The total area irrigated by them was 1,324,000 acres. The value of food grains raised on two works, the Western Jumna and the Bari Doab canals, was $14,400,000. It may, without exaggeration, be reckoned that one-half of these crops would have perished if unwatered, or would not have been raised at all if the canals had been absent, so that in that one year alone the wealth of the Punjab was increased by these two canals by $7,200,000, an amount equal to about two-thirds the cost of the works, and but for the protection they afforded the Government would have lost heavily from the necessity of remitting revenue and otherwise providing for famine relief. The net revenue for the year in the Punjab was only $610,000, being about 5½ per cent on the capital outlay on works in operation, a result which obviously supplies a wholly inadequate test of their value to the country.

Up to the year 1878 the capital outlay on canals completed in the Northwest Provinces had been $21,800,000. The area irrigated that year was 1,461,000 acres, the value of the crop raised on which was estimated at $30,000,000. Half of the area irrigated was occupied by autumn crops, which but for irrigation must have been wholly lost, and it may be safely said that the wealth of these provinces was consequently increased by $15,000,000, so that three-fourths of the entire first cost of the works was thus repaid to the country in that same year. The net revenue to the Government from irrigation in these Provinces was $1,550,000, or 7¼ per cent on the whole capital outlay of $28,750,000, of which about $6,250,000 was still unproductive.

The results of irrigation are not so favorable in Bengal and Behar as in the above two provinces, chiefly because irrigation is there less necessary since the rainfall is more abundant. There is sufficient evidence of its value in Madras. The three great deltaic systems of irrigation, the Godaveri, the Kistna, and the Cauveri, yield direct returns of 8, 6, and 31 per cent, respectively, on the capital spent on them. During the year 1876-77, a year when every unirrigated district was importing a large part of the food of its population, the value of rice produced in the deltas of the Godaveri and Kistna rivers is calculated at the prices then prevailing to have been not less than $25,000,000. The ordinary rental of land in northern India is doubled by irrigation, while in 11 districts of Madras the average rental rises from 40 cents to $1.70 per acre. In considering this question it should be borne in mind that there are other causes of financial ill success of irrigation works: the one temporary, the other permanent. In the one case the works may fail to pay for a time because of the slowness with which the people adapt themselves to the new system of cultivation, a difficulty which arises in almost every new work, or because of errors in the details of the scheme which experience detects and which are easily remedied. In the other case the failure may be due to the inherent defects of the scheme and to the fact that the water costs more than it is worth. In the former case there may be reason to expect that the water will be eventually fully utilized and the deficit be converted into a surplus, though the accumulated excess charges during a series of years may amount to a large sum which receipts will only gradually wipe out. In the latter case, though there may be room for improvement and economy in the distribution and use of the water, it may be impossible ever to realize a surplus.[a]

According to the same authorities the net income of the whole works in operation in British India was in the year 1879–80 $5,830,000, which amounts within a very small fraction to 6 per cent of the whole capital, including about $16,250,000 spent on works not yet brought into operation. If this part of the outlay be excluded the income is found to be more than 7 per cent on the capital actually utilized. Compilation of the administrative reports of the various provinces of India shows a total expenditure in the first ten years of work (1867–1876) on defined projects to have been $52,850,000. Between 1877 and 1900 the gross outlay was $285,000,000, the grand total expended on such work from 1867 to 1900 being $337,850,000. In the year 1900–1901 the expenditures on account of irrigation aggregated $11,500,000 and the revenues $12,075,000, the profit earned on the capital outlay being 7.5 per cent.

The following statement of the water rents derived from the use of the Western Jumna canal in the Punjab between the years 1820 and 1850 will give a fair idea of the rapidity with which the income from the use of irrigation works increases. In 1820 the water revenue was $420 per annum; in 1830 it was $28,800; in 1840 it was $112,900. On the Eastern Jumna canals in the Northwest Provinces the water revenue was in 1830 $3,000 per annum. In 1840 it was $29,300 per annum, and in 1845 it was $48,200 per annum.[b]

---

[a] Report of the Indian Famine Commission, Part 2. London, 1880.

[b] Smith, R. Baird, F. G. S., Italian Irrigation, London, 1855, vol. 1, 318-340.

LAND AND CROPS.

The following table gives the area and population of the principal provinces of India according to the census of 1901:

Area and population of principal provinces of India.

Province.	Area.	Population.	Density per square mile.
	Square miles.		
Bengal	151,185	74,744,866	494
United Provinces and Oudh	107,164	47,691,782	445
Punjab	97,209	20,330,339	209
Central Provinces	86,459	9,876,646	114
Madras	141,726	38,209,436	269
Bombay	123,064	18,559,561	151
Burma	236,738	10,490,624	.....
Other provinces	143,704	11,996,343	.....
Total British territory, including Burma, etc	1,087,249	231,899,597	232
Total native States	679,393	62,461,549	92
Grand total, India	1,766,642	294,361,046	162

Of British-born inhabitants, in 1891 there were 100,551; of agriculturists, 171,735,000, or 60 per cent of the whole population; and of manufacturers, 27,470,000. The mortality in India varies from 21 to 28 per thousand.

The following table shows the areas cultivated and irrigated in the various provinces during the year 1900–1901:

Area cultivated and irrigated in principal provinces of India.

Province.	Acres cultivated.	Acres irrigated.	Net revenue.
Bengal	51,607,700	716,271	$13,066,000
Madras	24,509,613	6,579,284	18,854,000
Bombay	21,000,594	.....	9,791,000
Northwest Provinces	25,614,892	1,800,000	15,107,000
Punjab	24,521,071	6,000,551	9,561,000
Oudh	8,965,323	.....	5,181,000
Central Provinces	15,250,582	.....	2,908,000
Sind	3,729,433	2,568,503	3,129,000
Others, including Burma	23,116,657	946,497	13,286,000
Total, including minor subdivisions	198,315,865	19,538,923	90,883,000

Counting irrigated areas cropped twice, the total acres irrig[illegible] were [illegible], and counting areas of all kinds cropped more [illegible] once, the total area under cultivation was [illegible] acres.

The following table gives the areas under cultivation of the prin[illegible] crops produced during the same year:

Extent and character of crops.

Crop.	Area under cultivation.	Crop.	Area under cultivation.
	Acres.		Acres.
Rice	[illegible]	Tea	[illegible]
Wheat	[illegible]	Indigo	[illegible]
Other food grains	[illegible]	Tobacco	[illegible]
Sugar cane	[illegible]	Total, including other crops	[illegible]
Cotton	[illegible]		
Oil seeds	[illegible]		

Irrigation works for which accounts were kept paid 7.5 per [illegible] interest in 1897-98 on the capital outlay. The estimated value [illegible] irrigated crops in that year was [illegible].

It will be observed from the first table that the proportion of [illegible] irrigated to the total area under cultivation is very large, one-si[illegible] the whole being irrigated. Since the introduction of improved i[illegible] tion works and the great increase in the area of land brought u[illegible] [illegible] the more valuable food c[illegible] [illegible] competition with [illegible] increased. The producti[illegible] [illegible] the American civil war. [illegible] Since then the exports o[illegible] [illegible] and now its average is o[illegible] [illegible] is pro[illegible] [illegible] Provinces, Sind, and [illegible] [illegible] per [illegible] as valuable as th[illegible] [illegible]

[illegible] in recent ye[illegible] [illegible] does not thrive [illegible] [illegible] The Punjab is the [illegible] [illegible] Northwest Provinces, Oud[illegible] and Bengal south of the Ganges. In the Central Provinces [illegible] [illegible] Bombay and Sin[illegible] [illegible] and all India has an area under wheat one-third as [illegible] as has the United States. The [illegible] per acre is rather smal[illegible] the Punjab it is [illegible] bushels per acre; in other places a trifle m[illegible] [illegible] Wheat is an autumn crop and is all irrigated. To the

uction of the great canals of the Punjab and Northern Provinces is e the quality and prominence which it possesses.

Rice is an extensively cultivated crop, but it is limited to the deltas the Orissa, Godaveri, and other large rivers and to Bengal; 80 per ɔt of the crops raised in such regions is rice. Elsewhere little is ɔwn excepting in the lowlands along the coast. In Bengal the aver- e yield per acre is 1,200 pounds of clean rice. Millet is more tensively and generally grown than any other crop excepting in ɜ special rice districts. A variety of sorghum called jowari and a iked millet called bajra are the most common varieties. They are ɪt weather or spring crops and are used somewhat by the natives for ɔd, but are chiefly used as fodder. Oil seeds form an important ɔp. These are usually grown as a second crop after rice and pulses. l is extensively used in India for lamps and for food. The largest l-seed producing provinces are Bengal and the Northwest, but these ops are also extensively grown in Madras and elsewhere.

All kinds of vegetables and fruits are produced everywhere in India, ese being the chief food of the natives. Among the more important nds are potatoes, which are grown especially in the hills, maize, matoes, eggplants, mangoes, oranges, lemons, melons, figs, plantains, ıd cocoanuts. Cocoanut palms are grown most abundantly on the ɜst coast lowlands, and date palms in Bengal. The production of e ordinary spices is rather abundant. They are mostly, however, r home consumption, for use in curries, etc., as tumeric, chile, chic- y, coriander, and others. Sugar cane is very extensively cultivated roughout India, especially in the Northwest Provinces, and in Bom- ɣy, but it is an expensive crop to produce, both because of the time quired to mature it and the amount of water necessary to irrigate The varieties of sugar cane produced in India are not equal to ose produced in America and in the West Indies, the proportion of ɜcharine matter being comparatively low.

Jute is a plant almost exclusively produced in India and very exten- ɾely exported. It is chiefly grown in northern and eastern Bengal. digo is extensively grown in the Northwest Provinces, Punjab and ıdras, chiefly by the natives. It is most extensively produced, how- er, in Behar by English capitalists. The expense of making the e from the plant is such that the natives are seldom able to culti- te and manufacture it; hence the factories are usually under the ntrol of British capital. Poppy for the production of opium is ɔwn extensively in the Ganges Valley near Patna and Benares, and central India. Its cultivation requires much care and attention d is usually an indication of intelligence and prosperity on the rt of the cultivators. Tobacco is generally grown in small quanti- ɜs everywhere in India. The best is produced in Madras, whence e variety known as Trichinopoly is extensively exported. Coffee is oduced in small quantities in southern India only. Tea is exten-

sively cultivated in Assam, where it is indigenous, but it is
about Darjeeling in the foothills of the Himalayas. It is
sive crop to prepare for market and is cultivated chiefly by
Its quality is constantly being improved and the amount
annually increasing.

The advantage of using manure is apparently well unde
if not extensively used it is because of the limited means
vators. The rotation of crops is not generally practiced,
to the extensive use of water for irrigation it does not se
necessary. The soil throughout India differs essentially
localities; it is generally very fertile on the great Gang
while the black cotton soil of the Deccan is perhaps the
in the world.

The kharif or wet-weather crop is matured chiefly by
the summer monsoon. It is sown as soon as the spring rai
of the plowing of the land, and it is reaped in September
The rabi or autumn crop is the dry-weather crop and r
largest amount of artificial watering for its cultivation.
October and is reaped in March or April. The principal
duced during the wet season are rice, cotton, sugar cane, e
the autumn season the more hardy grains are produced, es
food grains, such as wheat, barley, etc. The millet and fo
are chiefly sown in the higher lands and depend for the n
natural rainfall, as their requirements in the way of water
less than those of other crops.

CHAPTER II.

TOPOGRAPHY, METEOROLOGY, AND FORESTRY.

TOPOGRAPHY AND GEOLOGY.

India includes within its borders the highest mountains in the world and some of the mightiest rivers and greatest plains. Topographically it may be divided into three distinct parts, each possessing different topographic features. First, the Himalayas, which form a great mountain barrier on the north and shut out the rest of Asia, forming a controlling factor in the climate and physical geography of India; second, the plains of the great rivers issuing from the Himalayas, the Indus and Ganges plains; and third, south of these plains a high, steep-sided table-land supported by the Vindhaya Mountains on the north and by the western and eastern Ghauts on either side of the peninsula. This great interior table-land is broken by many peaks and mountain ranges separated by broad and fertile valleys.

The Himalayas take their name from an Indian word which means literally "dwelling place of snow," and consist of a great mountain range 1,500 miles long, the general trend being from northwest to southeast. This mountain range may be likened to the Sierra Nevada, bordering the eastern side of the great California Valley. Approached from the southern or plains side there is the same general appearance of low, rolling foothills, the higher peaks being so far back from the edge of the valley as to be scarcely discernible. This mountain range or aggregation of mountain ranges is also similar to the Sierras in its composite formation. On top and behind it is a high arid plateau which corresponds to the Nevada desert.

The highest peak in the Himalayas is Mount Everest, 29,002 feet above the sea, while peaks above 20,000 feet elevation abound in all parts of the range. There are numerous well-traveled trails leading from India through Kashmir and Nepal into Tibet and China, and the passes on these are from 16,000 to 19,000 feet high, and for several days the traveler remains above 16,000 feet in altitude. Only one pass is as low as 16,400 feet.

The Indus River rises well north of the first great range of the Himalayas and drains nearly half of their northern slope, and after flowing around the western extremity of the range it turns and flows southwardly, being joined by various tributaries which drain the southern and western slope. Its main drainage area is situated at a great

altitude among the glaciers of the Himalayas. Its drainage basin in the Himalayas alone is about 32,550 square miles in area, while with its affluents the whole basin drains 311,600 square miles. This river, with its branches, affords the chief source of water supply and drainage to the provinces of Punjab and Sind.

The northeastern slope of the Himalayas is drained by the Brahmaputra River, which, like the Indus, rises north of the mountains, draining about one-half of their northern slope, and after breaking through the Himalaya Range it flows westwardly through the valley of Assam to its junction with the Ganges River, 100 miles from the sea. The drainage basin of the Brahmaputra north of the Himalayas is about 95,000 square miles in area. Like the Indus, its upper basin is at a great altitude. As yet its waters are but little used for irrigation, as the country through which it flows generally receives a fair rainfall. The average elevation of the Indian watershed between the headwaters of the Brahmaputra and Indus rivers is above 18,000 feet in altitude.

The Ganges River and its tributaries drain the larger portion of the southern slope of the Himalayas. The catchment area above an elevation of 1,000 feet is very small relatively to that of the Indus and Brahmaputra, while the total catchment area is 414,000 square miles. This river flows eastward through the great plains of the Northwest Provinces and Bengal to its junction with the Brahmaputra, whence it flows southward to the Bay of Bengal. The southwestern slope of the Himalayas, in the province of Punjab (which name means "The Five Waters"), is drained by the main five tributaries of the Indus, viz, the Sutlej, Ravi, Chenab, Jhelam, and Indus rivers, all of which join below Mooltan, whence they flow southward to the Arabian Sea. All these rivers are extensively used in irrigation.

The southern foothill ranges of the Himalayas north of the Punjab and the Northwest Provinces are from 3,000 to 4,000 feet high, and are called the Sewaliks. Between the Sewalik Hills and the sub-Himalayas is a disconnected line of valleys from 2,000 to 2,500 feet in altitude. These valleys are called the Duns. The sub-Himalayas, which form a higher range or belt of hills north of the Duns and between them and the main range, are from 15 to 50 miles in width north and south, and are sometimes separated by several successive dun-like valleys. These latter are artificially drained and cultivated in places and are very fertile. In the sub-Himalayas are the mountain resorts of the various provincial governments of India, at altitudes varying between 7,000 and 8,000 feet. In a portion of the northern or Gangetan Plain to the east of the Ganges is a broad belt from 10 to 15 miles wide. It is a broad, grassy tract, traversed by sluggish streams, with extensive morasses and marshes, and is called the Tarai.

The great northern plain stretches with an unbroken surface along the foot of the Himalayas from the upper Indus in Punjab to the Ganges delta near Calcutta and in a wide valley along the Brahma-

utra called Assam. Its area is about 500,000 square miles, and it is owhere above 1,000 feet in elevation and appears to be perfectly flat. he northern, central, and eastern portions are well watered by rivers aving their sources in the Himalayas or in the Ghauts. Assam has periodical rainfall, and the whole of this northern plain forms the est cultivated, the richest, the most populous, and the most civilized istrict of India. This plain receives the water of four great river ystems—that of the Indus, of the Brahmaputra, and the combined anges, Jumna, Sutlej, etc., draining the southern Himalaya slopes, nd the Betwa, Chumbul, and Soane, draining the Vindhaya Mountains and northern Ghauts.

The third great topographic division of India is the table-land efore alluded to, generally called the Deccan, and includes the entral Provinces, Hyderabad, Bombay, Madras, and Mysore The ighest peaks of the northern Deccan are Mount Aboo, 5,650 feet igh, on the west and Mount Parasnath, 4,450 feet high, on the east, hile the hills generally vary from 1,500 to 4,000 feet in altitude and onsist of ridges separated by broad, high plains and masses of forest.

The eastern and western Ghauts are great, irregular ranges of mountains, extending the whole length of the eastern and western coasts. he eastern Ghauts average 1,500 feet in elevation; the western hauts ascend sharply from the sea to an average elevation of 2,000 eet, with peaks varying from 6,000 to 8,700 feet in height. The vestern slope of this range is extremely rugged, having much the ppearance of the mesa edges in the western United States. The astern Ghauts are a series of broken spurs, not continuous like the vestern Ghauts, and afford easy access to the interior. The inner plateau between these mountain ranges is from 1,000 to 3,000 feet in levation, dotted with peaks and ranges over 4,000 feet in elevation, nd it is approached through the western Ghauts by only a few difficult passes. The general appearance of this country is very similar o that of northern New Mexico and Arizona and of southern Utah.

The western Ghauts form the watershed of the central plateau. Only short streams flow from them into the Indian Ocean, the main drainage making its way eastward across the central plateau, breaking through the eastern Ghauts and emptying into the Bay of Bengal. The chief rivers, viz, the Godaveri, Cauveri, and Kistna, rise in the western Ghauts; their deltas in Madras form extensive and fertile plains, which their waters irrigate. The chief population of this central region is on the eastern slope, and here irrigation is extensively practiced, not only from great rivers in their lower or coast levels, but also by means of storage in the western portions of Madras, Mysore, and in Bombay. Of the important rivers of this region the drainage basin of the Godaveri is 119,000 square miles; that of the Kistna is 59,500 square miles, and that of the Cauveri 30,300 square miles in area.

The flood discharges of the various great Indian rivers are enor
The Indus above Sakkar discharges as high as 380,000 second-
which is equivalent to 15 second-feet per square mile of catchr
The Ganges in flood may discharge 1,350,000 second-feet, whi
a little less than 5 second-feet per square mile of catchment
Godaveri discharges in great floods 1,350,000 second-feet, or 11 se
feet per square mile; the Kistna a little less than 1,200,000 second
and so small a stream as the Soane, rising in the Vindhayas, w
catchment area of about 34,000 square miles, discharges 1,70
second-feet, equivalent to 50 second-feet per square mile of catchr
One river in southern India, the Gadanamathi, having a catch
of only 29 square miles, discharges in flood 28,000 second-feet, c
second-feet per square mile, and other rivers discharge nearly as
relative amounts.

The following table, giving some details of discharges, etc., of
ous large rivers near their mouths, is taken from Heywood:[a]

Discharges of large Indian rivers.

Rivers.	Extreme breadth of river bed.	Extreme breadth of channel.	Least breadth of channel.	Fall per mile.	Rise in monsoon.	Gre dep dry s
	Miles.	*Miles.*	*Miles.*	*Feet.*	*Feet.*	F
Ganges	5¼	2¼	1¼		27	
Kistna	1½	1½	¾	1.17	35	
Godaveri	4	2½	1½	1.09	30	
Cauveri	1	¾	½	3.5	12	

Rivers.	Surface current in floods per hour.	Flood section.	Flood discharge per second.	Least discharge in dry season per second.	Longest duration of flood.	A (
	Miles.	*Sq. feet.*	*Cubic feet.*	*Cubic feet.*	*Days.*	*Sq*
Ganges	4 to 7	288,000	1,800,000	45,000	40	
Kistna	7½	153,000	1,500,000	1,125	10	
Godaveri	4½	216,000	1,500,000	2,250	10	
Cauveri	6	37,800	300,000	None.	10	

The geology of India varies with the topography. The great n
ern plain is an alluvial deposit, on the surface of which not a p
can be found excepting near the foot of the hills. It prol
belongs to the post-Tertiary, judging from a few fossil mam
fishes, and crocodiles which have been found, and is probabl
result of delta deposits. The Sewalik Hills also belong to r
geologic times and are composed of micaceous sandstones, i
spersed with bits of clay and marl, their age being Miocene or
cene. The sub-Himalayas belong to the Tertiary epoch and a

[a] Jackson Hydraulic Works, London, 1885, p. 250.

marine origin, composed chiefly of sandstones, argillaceous shales, schists, and limestones. The main range of the Himalayas is composed chiefly of schistose rocks, mica-schists, and gneiss, and some granite and limestone.

In the Deccan the oldest rocks consist of gneiss, which is found in large portions of Bengal and Madras and is pre-Silurian. The great mass of the central plateau, perhaps 200,000 miles in area, consists of what is known as Deccan trap, which forms the most striking physical feature of the landscape. Most of the great ranges of mountains, with their rugged outlines and the square buttes or ghauts and mesas, are the denuded edges of basaltic flows. It is from these jagged or step-like ranges that they receive their name of ghauts, which means "steps." The soil is largely composed of disintegrated laterite, a ferruginous and argillaceous rock occurring over the trap but also found elsewhere. High-level laterite is usually a result of the decomposition of trap, and the soil of much of the central plateau which it forms is very poor in quality. Low-level laterite is more sandy, often containing gravel, and forms most of the better soil fringing the coast.

METEOROLOGY.

The rainfall in India is exclusively from the evaporation of the Indian Ocean and the two bays which surround the peninsula. The distribution of rainfall is extremely variable, ranging from a couple of inches per annum in portions of the Sind to over 600 inches in a limited area in Assam. By far the greater part of the rainfall is brought direct from the ocean between the months of June and October by the regular periodical wind known as the summer monsoon. In upper India the cessation of the summer rains is followed by a rapid fall of temperature under a perfectly clear and cloudless sky. A cool and dry current sets in from the northwest, down the Ganges Valley toward Bengal and from the north across the northern Deccan, south of which it turns and sets toward the Bombay coast. The plateau of Hyderabad, Madras, and Mysore receives a small amount of rain in October and even later. In lower Bengal and on the coast a few inches of rain are expected in October and are of importance to the late summer crops and in sowing or germinating cold-weather or autumn crops. The latter part of October and November and the earlier portion of winter in northern India are generally rainless. The late winter rains, which are small in amount and are regular only in upper India, rarely set in much before January.

With regard to this periodic distribution the rainfall in different parts of India may be summarized thus: From June to September rain falls more or less heavily throughout the entire area, excepting upon the dry plains of the Sind, where it is extremely rare and sometimes fails altogether. In a portion of the Punjab and in the Carnatic the summer rain is restricted to occasional showers. In October, when

the rains have ceased in upper India, Bengal, etc., the heavy rains of Madras set in and continue until the middle or end of December. About this time begin the light rains of upper India, which are experienced in the Northwest Provinces and fall at intervals to the end of March, after which the dry season continues till the end of June, the beginning of the monsoon. In lower Bengal and in Assam the rains become more frequent from January on, and are chiefly afternoon storms. On the coast of Malabar they are earlier than in Bombay. In Madras occasional showers are expected after February, but the steady rain begins only in October.

In the Ganges delta the mean annual precipitation is from 60 to 70 inches. On the great plain, including the Northwest Provinces, it averages 40 inches, and at the summit of the great plain west of Delhi it varies from 25 to 30 inches per annum. At the mountain stations in the sub-Himalayas the annual precipitation ranges from 90 to 120 inches. Farther in the Himalayas, at an elevation of 10,000 feet or above, the rainfall is only 10 or 20 inches, while the snowfall may be 6 to 8 feet or more. There is a difference of from 10 to 15 inches between the precipitation over the southern and northern portions of the Gangetan Plain. In the Punjab the highest average precipitation is in the sub-Himalayas, where it is 68 inches per annum. At Mooltan it is but 7 inches per annum, which is a low average, and at Dera Ismail Khan the annual precipitation is 8.2 inches per annum, nearly the average of the Punjab. In central India the annual precipitation in the lower lands varies between 20 inches at Jeypur and 32 inches at Khundwa, while the minimum in the mountains, such as Mount Aboo, is 61 inches.

In the Northwest Provinces the general average is 26.5 inches at Muthra or Agra, while Aligarh has a minimum of 24 inches. In Bengal the maximum average on the coast is 105 inches, and the minimum average on the plains at Patna is 38 inches. In Assam at Chara Punji the maximum average of the world is reached in an annual precipitation of 368 inches, while in the same place in 1861 30 inches fell in twenty-four hours and 805 inches fell during that year. In Bombay in the western Ghauts the maximum average is 250 inches, and the minimum average in the lowlands at Duhlia is 17 inches. The general average of Bombay is 67 inches. In the Sind the maximum average of 16 inches is at Negar, and the minimum average, 4.3 inches, at Jacobabad. In Madras the highest annual precipitation is 132 inches at Manalore and Calicut; the lowest at Belary and Tuticorin is from 16 to 18 inches, the average of Madras being 44 inches.

The following average annual temperatures at different points in India indicate the tropical character of the climate and the small percentage of cold weather which prevails. At Trichinopoli and Madras, on the southeast coast, the annual averages are 82.8° and 82.4°, respectively. On the southwest coast, at Goa and Cochin, the annual aver-

age temperature is nearly 80°; at Calcutta it is 79.2°, and at Bombay 78.8°, the latter city being the coolest of the three presidency towns. At the hill station of Simla, at an elevation of 7,100 feet, the average annual temperature is 54.4°. The highest monthly temperature occurs at Mooltan in June, and is 95°; at Delhi it is 94.3°. The lowest monthly temperature is at the high hill stations, being at Simla 39.6° in January.

FORESTRY.

In recent years the British Indian government has paid much attention to the preservation of its forests, and is now reaping the benefit in the large income derived from the sale of timber.

The establishment of the government department of forestry is of recent date, brought about by the destruction of forests for fuel, for charcoal, and other wasteful causes. In 1844 and 1847 the subject was first taken up by the governors of Bombay and Madras. In 1864 Dr. Brandis was appointed inspector-general of forestry, and in 1867 the regular training of forestry officers was commenced at the schools of France and Germany, where it is still continued. At present discriminate timber cutting is allowed, but the burning of hill brush is stopped; the forest areas are surveyed and demarked, plantations laid out and maintained, and forestry conservation otherwise carried on.

Forests are classified as reserved and open. The former are the immediate property of the State and are managed by the forestry department, their development being a source of wealth. Cattle are excluded from them, destructive crops and undergrowth destroyed, and the cutting of timber is strictly regulated. The open forests are less carefully guarded, but certain kinds of timber trees are protected. Large amounts of money are annually spent in the plantations, and wherever needful young trees are planted to replace those removed. In 1878 there were 12,000,000 acres of reserved forests. The revenue was $3,320,000 and the expenditures $2,000,000, showing a fair net profit. Ten years later, in 1888, there were 43,520,000 acres of State forest land, the net revenue after deducting all working expenses being $2,020,000.

The British officials generally hold that the effect of forest denudation on rainfall is doubtful and much disputed. Contrary to what might have been expected, there is no evidence to show whether the actual rainfall has decreased or increased in consequence. They all agree, however, that forest destruction has acted injuriously by letting flood waters run off too rapidly and that these waters are lost. They also do much damage as floods. Three-quarters of a century ago immense tracts of southern India were overspread with jungle and the slopes of the Ghauts were universally timber clad. Most of the level woodland has since been cleared for cultivation and the timber cut down for fuel. But another and scarcely less evil has

resulted. Formerly the water was partially protected from evaporation by the sheltering trees. Its flow on the surface was mechanically reduced by the jungle grass and tree trunks; it had time to be absorbed by the vegetable mold and to sink into the earth, thereby insuring the permanence of the natural springs. Not till this was done did the residue find its way to the rivers, and then at a comparatively tardy pace. Now, however, as a rule the rivers are in violent flood for about as many days as they used to be for weeks in moderate flood.[a]

---

[a] Thornton, W. T., Journal of the Society of Arts, London, 1878, vol. 26, p. 279.

CHAPTER III.

HISTORY AND ADMINISTRATION.

HISTORY OF IRRIGATION WORKS.

mong the first mention made of the irrigation works of India are se of Arab historians of the works constructed by the early Mo- amedan emperors in the Northwest Provinces and in the Punjab. all works, especially tanks, probably existed at much earlier dates outhern India.

; is related that about 1351 A. D. the Emperor Feroze Toghlak lt 50 dams across rivers for the promotion of irrigation and 30 ervoirs for irrigation purposes. The first important canal specific- mentioned was built by the same emperor, and was taken from Chouting River to Hansi and Hissar. Fifty years later this canal ame partly disused after the emperor's death. The next important ation of irrigation work is that the great Emperor Akbar constructed, .567, a canal from the river Jumna. It is stated that this canal constructed by the aid of forced labor, but the laborers had privi- es thereafter of using the water, and the superintendent saw that parties, rich and poor alike, received their share. This was the t Western Jumna canal. In 1626 the Shah Jehan had the cele- ted architect, Ali Murdan Khan, construct the Delhi Canal, which ows much the same line as does the present Western Jumna. At t this canal was constructed on a high bank following the water rses, but the banks burst and the canal became inoperative. The hitect then ran a new line as far as Delhi, following the water- d. On this canal an escape was introduced for the discharge of plus water. It had one channel 60 feet in depth cut through solid k. About 1753 these ancient Mogul canals ceased to exist, owing he decline of the Mogul power and to the constant wars, which at t time prevented their being kept up.

'he Eastern Jumna Canal was also begun by Ali Murdan Khan and ded at the foot of the sub-Himalayas. This canal reached to Sahar- our and beyond. It was abandoned after the first season, owing to bad alignment, as it was constructed in the lower drainage lines l bottoms. In 1780 Zabita Khan reopened this canal, but it was ried away during the first season and was then abandoned.

'he first of the modern irrigation works of magnitude was com- nced under the Marquis of Hastings in 1817, when Lieutenant ine established the head of supply of the Western Jumna canal at

a point high up on that river. This work was practically a restoration of the old Mogul canal, following and using the low lines of drainage to Delhi. No bridges were constructed and only earth embankments were used. The new development of these canals is due to Col. John M. Colvin, who in 1820 extended the above project beyond Delhi, and constructed many bridges and drainage works. Ten years later the earth banks across the drainages of Patrala Sombe were replaced by masonry dams.

The line of the Eastern Jumna canal was surveyed in 1822 by Lieutenant Debude, and the canal was opened in 1830. The ancient bed was cleared to a depth of 4 feet below the surface level and in general a new alignment was made which was fairly good, following up the highest divide or watershed. Owing to the steepness of fall given at first the levels retrograded and nearly destroyed the canal. Colonel Cautley rectified this by the introduction of falls, and in 1840 he introduced better works for the passage of side drainage.

Up to this time the irrigation works of India had been constructed chiefly by the East India Company. In 1858 the Government granted the Madras Irrigation Company and East India Irrigation Company 5 per cent on the capital invested, and these companies commenced the construction of works, the Government retaining considerable command over their operations, inspecting the plans and sanctioning the expenditures. Both of these experiments proved costly failures to the State, and in 1867 the Government purchased the works of the East India Irrigation Company when the latter was practically bankrupt. The Madras Irrigation Company has succeeded only one year in paying working expenses, but still carries on work under Government guaranty.

In 1867 the Government decided to construct its own irrigation works and great activity prevailed at once, the Government irrigation force being largely increased. In 1869 schemes for ten years' work, involving $150,000,000 expenditures, were outlined, and the following sums were expended: In 1867, $1,096,000; in 1868, $2,344,250; in 1869, $10,040,000, and so on. The total expenditures for the first ten years actually amounted to $52,850,000. Since then the Government works have generally proved satisfactory investments, and as they have certainly added to the wealth and prosperity of the country and have mitigated the severity of famines, large sums have been annually appropriated for the maintenance of existing works and the construction of new ones.

ADMINISTRATION AND LEGISLATION.

The administration of the irrigation works of India is conducted by the public works department, and the engineers are all civil servants in the employ of the British Government. Their status is fixed by law, their promotions are usually by seniority, as in the army and navy,

and, like the members of those branches of the governmental service, they receive stated salaries, according to the grades they occupy. They are entitled to leaves of absence and furloughs, and are retired with pensions after certain periods of service.

By parliamentary act of August 2, 1858, all the territory of India was vested in Her Majesty the Queen. All tributes and payments are received and disposed of in her name. In the British cabinet the secretary of state for India was vested with the powers previously held by the board of control under the old East India Company régime, and later on, by act of January 1, 1877, at Delhi, India, Her Majesty assumed the title of Empress of India.

The executive authority of India is vested in a governor-general called the viceroy, who is appointed by the Crown and acts under orders of the secretary of state for India. He is empowered in council to make laws for all persons, whether British or native subjects, foreign or otherwise. The governor-general has a council of seven members, whom he consults in the formulation of all laws.

Of the larger presidencies the governors of Bombay (including Sind) and of Madras are separately appointed by the Crown, and have each their own council and civil service, and in all orders they directly address the secretary of state. Bengal and the Northwest Provinces have lieutenant-governors and a legislative council, but these officers are appointed by the governor-general of India. The other minor provinces have lieutenant-governors or commissioner magistrates, but no councils or legislative powers. Each province is divided into districts, at the head of which is a deputy commissioner. Below this officer is a commissioner and joint magistrate, a deputy collector, and minor officers.

India is divided into British territory and the native states. The former is governed as above described, the latter by native princes, with the help and advice of a resident at his court who is called a political agent and whose duties are purely diplomatic. The highest land officer in nonregulation provinces, as the Central Provinces or the Punjab, is a deputy commissioner. This officer collects revenues and administers civil justice. He is the unit of administration, the sole responsible head of his jurisdiction, and on his energy and character largely rests the efficiency of the Indian government. In India there are 252 districts under deputy commissioners. These districts each average in area 3,800 square miles, and have each an average population of 800,000. They are divided into divisions, and these again subdivided into the ultimate unit of subdivision, which is known as a tahsil. The subdivision is in charge of an assistant magistrate or executive officer, and the tahsil is in charge of a deputy collector or fiscal officer. Land is the main source of revenue of the Indian government, and hence the levying and collection of the land tax is the main work of the administration of that government.

In Bengal permanent settlements have been largely made. The zemindar or headman of a village makes the payment for the whole village to the government, he taking from each cultivator his portion of revenues and retaining for himself a proportion of the same. In Madras the cultivator is the rent-paying unit, as the zamindar is in Bengal. In Bombay revenue settlement is proceeded with as elsewhere, only in more detail, by a careful revenue land survey. Each field is marked out, measured, and assessed separately. This method is simple, as the government recognizes only the owner of each field. With these owners terms of settlement are made for periods of thirty years. In the Northwest Provinces and the Punjab the village is taken as the unit, as is the case in Bengal, and the payment is made to the government by the village. Terms of settlement are also made there for periods of thirty years.

In order to convey a clear understanding of the method of promoting irrigation development in India, it is essential first to give a brief outline of the present attitude of the English rulers toward irrigation. At first the government permitted private corporations to construct and operate irrigation works, the earliest work planned by British engineers being undertaken by a private corporation on a guarantee of interest by the East India Company. During the last thirty years the government has been active in the promotion and construction of nearly all good works projected. These projects are studied, examined, and reported on usually several times during a series of years, and when the government is finally satisfied with them, either as financial investments or as measures for the relief or prevention of famine, the work is sanctioned and the funds for its construction appropriated.

The government of India is as a rule greatly in favor of the extension of irrigation works. It encourages enterprises by granting loan funds for the construction of works whenever it can be proved that profits, increase of interest, and all the maintenance charges will probably be derived. It also constructs works as a means of famine relief in certain places, even when profits can not be obtained. The government further fosters the use of irrigation waters by making the water rates very low, or by even giving water away in years of scarcity. As shown in the succeeding acts, the government of India has entire control over all sources of water supply, and so exercises it as to make it the greatest benefit to the community at large. The powers of control over the waters for irrigation are entirely centralized.

Each province of India has a separate branch of the Public Works department, known as the irrigation branch, at the head of which is a chief engineer, generally also secretary to government of that province, and over all the chiefs of engineers is an inspector-general of irrigation, attached to the staff of the governor-general of India. The officers in the upper grades of the irrigation branch are nearly all

ropeans, and are recruited from the royal engineers, or from civil gineers educated in well-known colleges either in England or India. e civil engineers from England receive a technical education at opers Hill College, and the majority of those from India are edu- ed at the Thomason Civil Engineering College at Roorkee, or at the leges in Bombay or Madras. The lower grades of officers are com- sed of selected noncommissioned officers and soldiers and from tives who have passed an examination after studying for a period some college.

The chief engineer is the head of the department in the province, d this latter is divided into circles presided over by superintending gineers. Each circle is again divided into divisions, over which secutive engineers preside. Each division is again divided into sub- visions, of which there are generally several under the charge of an istant engineer. This concludes the list of the upper grades. der the assistant engineers again come the lower grades of subor- nates who have charge of the different works.

Besides the engineering establishment proper, there is the revenue ablishment, which works in conjunction with it, and whose duties mostly concerned with the administration and the measurement the fields for assessment. This establishment consists chiefly of tives, and is presided over by a deputy magistrate, under whom are ahdars, ameens, and patrols.

All of the upper grades—that is, from the assistant engineers upward, luding the deputy magistrate—have to pass an examination in canal r, and are given magisterial powers, which enable them to inflict nishments for breaches of this law. The powers conferred vary th the standing of the officers. The executive engineers may pass estimates within certain limits connected directly with the construc- n or maintenance of works in their division. All estimates involv- considerable expenditure are sanctioned by the superintending gineer within certain limits, beyond which the sanction of the chief gineer, practically that of the government of the province, is required. l large projects, such as a new canal system or storage reservoir, s to the inspector-general, and are referred by him to the govern- nt of India and to the secretary of state.

The rules and regulations by which water is served to cultivators detailed in the canal acts given further on. In irrigating districts ter is served to cultivators on certain days, very often on three days one week, or possibly they are allowed to use it during one week d are deprived of it for another. The period in which they are not owed water is known as a period of "tatil," an Indian word mean- closed. Breaches of "tatil," or the taking of water when its use is t allowed, render the individuals committing the act liable to fine or prisonment. The executive engineer of the division has entire con- l over the distribution of the water, and complaints regarding scar-

city, repairs, misappropriations of water, etc., are all referred to him, and he either decides them himself or empowers the supervisorial officer or deputy magistrate to do so. The assistant engineer is generally a European, and his right-hand man, as far as irrigation matters are concerned, is the deputy magistrate, who is generally a native of some standing and education. The assistant engineer has magisterial powers, and his time is largely employed in trying cases and settling disputes. Zilahdars, of which there are generally two under the assistant engineer, have under them 5 or 6 ameens, under whom are from 8 to 10 patrols. These latter note the fields as they are irrigated, and when the irrigation is complete their measurement is made by the ameen, the whole being superintended by the zilahdar, who is held responsible for the correctness of the measurement.

The first act bearing with any importance on irrigation legislation was Act VII, by the governor-general of India in council, passed April 12, 1845, and entitled "An act for regulating the levying of water rent, tolls, and dues on certain canals of irrigation constructed by the government in the Northwest Provinces and the protection of said canals from injury." From clauses in this act the following extracts are made:

And it is hereby enacted that the said lieutenant-governor of the Northwestern Provinces shall be competent to draw out rules to regulate the levy of water rent and the supply of water for irrigation. * * * The rules thus drawn out shall be published for general information in the Government Gazette.

And it is hereby enacted that all balances of water rent due for lands irrigated by the canal shall be levied, either by temporary deprivation of the benefits of the canal or by the same process as is prescribed for the recovery of balances of land revenue.

And it is hereby enacted, that whoever willfully causes any obstruction to any of the said canals, or to any of the water courses drawn and supplied therefrom, or damages the banks of the canal, or the works constructed for its maintenance, or willfully defiles the water in the canal, shall be liable to the penalties hereinafter described.

And it is hereby enacted, that all persons offending against the provisions of this act shall be punishable, on conviction before the magistrate, by imprisonment without labor for a term not exceeding fourteen days, or fine to an amount not exceeding 50 rupees [about $25], or both; and in default of payment of such fine by additional imprisonment for fourteen days.

On May 31, 1845, the lieutenant-governor of the Northwest Provinces, under authority of the above act, passed resolutions regarding various canals, from which the following extracts are made:

In conformity with Section VIII of the aforesaid act, the superintendents of the said canals are invested with the powers of deputy collectors for the levy of rents, and of joint magistrates for the enforcement of penalties under the aforesaid act, and their assistants are declared competent to exercise the same powers under their directions and on their responsibility. The subordinate establishments of such superintendents have the power of subordinate revenue and police officers for the aforesaid purposes. An appeal lies direct to the commissioner of the division against orders passed by the superintendent or his assistants in the capacity

f deputy collector, and to the sessions judge against orders passed in the capacity f joint magistrate.

When it may be more expedient to give water on contract rather than according o the surface irrigated, the terms of contract may be as follows:

Where the water flows naturally, 2 rupees [$1] per annum for every square inch f opening taken from the summit level of the water and having a free course.

In the event of any person secretly taking water from the canal in ny manner, for which rent is leviable, without coming under engagements to pay the rent, or secretly taking more water than he has ngaged to pay for, he shall be chargeable with double rates for all vater so taken.

All land brought into cultivation within 20 yards of the canal or any branch tream from it, subsequently to the construction of the channel, shall pay water ent, whether taking water or not; and similarly all land cultivated from wells which have been dug or reopened within 20 yards of the canal boundary, or within 0 yards from any branch stream from it, subsequently to the construction of the anal, shall pay water rent, whether taking water from the canal or not.

When, from the carelessness of cultivators either in not properly closing the eads of their water courses or in leaving the water courses in bad order, the water verflows and spreads over waste or fallow land, a fine shall be levied not exceeding the highest rate of water rent leviable on the extent of land flooded.

It shall be in the power of the canal officers to close the whole of the branch water courses from sunset to sunrise for the purpose of forcing the water onto the lower parts of the canal; and also, when necessary, for any period not exceeding three days in a week. At other times the water shall be at the command of the cultivators, provided it be in the power of the canal officer to furnish a supply. Persons taking water once so as to benefit a crop shall be liable to the charge for the whole year, or the whole crop, as the rate may be leviable.

Special agreements between individuals and the superintendent for the use of water for irrigation, for driving machinery, or for other purposes, on other terms than are embodied in these rules, shall be constructed as other ordinary contracts are.

In addition to these, rules are laid down defining the powers of the superintendents and their assistants and other officers on the works, as well as rules giving the charges which villages or individuals are subject to who do not take water for irrigation, but who use it for watering live stock or for domestic purposes. The charges for filling reservoirs or tanks are also specified, as are the tolls for rafts or boats. The right of ownership of water was summarily settled in India in 1873 by the passage of "An act to regulate irrigation, navigation, and drainage in northern India." The preamble tersely states the claims of the government thus:

Whereas throughout the territories to which this act extends the government is entitled to use and to control for public purposes the waters of all rivers and streams flowing in natural channels, and of all lakes and of the natural collections of still water, etc.

This statement of rights is perfectly plain, and in India the government has no need to use its power to enforce these claims. This act is known as "Northwest canal provinces Act No. VIII, of 1873," and

lays down all of the fundamental laws governing canal [illegible] in those provinces.

The principal act establishing the laws covering [illegible] presidency of Bombay is Act No. VII of 1879, which w[illegible] 1881 by Bombay Act No. III. The preamble reads as [illegible]

Whereas it is necessary to make provision for the construct[illegible] and regulation of canals for the supply of water therefrom, a[illegible] rates for the water so supplied in the Bombay presidency, it is [illegible]

The act then goes on to define what are understood [illegible] courses, and drainage works, defines the various officer[illegible] law, with their powers, and makes the following furthe[illegible]

Whenever it appears expedient to the governor in council tha[illegible] river or stream flowing in a natural channel, or of any lake, or [illegible] collection of still water should be applied or used by the govern[illegible] pose of any existing or projected canal, the governor in council [illegible] tion in the Bombay Government Gazette, declare that the sai[illegible] applied or used after a day to be named in the said notification [illegible] than three months from the date thereof.

At any time after the day so named any canal officer duly [illegible] behalf may enter on any land, remove any obstruction, close an[illegible] any other thing necessary for such application or use of the sa[illegible] such purpose may take with him, or depute, or employ such [illegible] other persons as he deems fit.

Following this, equally broad powers are given [illegible] enter or examine land in connection with projected w[illegible] and regulate water supply, to enforce repairs, and pre[illegible] Additional regulations are formulated providing for [illegible] crossings, the removal of obstructions to drainage, and [illegible] tion of drainage works. Further:

Every owner of a water course shall be bound to construct all [illegible] for the passage across such water course of canals, water course[illegible] nels, and public roads existing at the time of its construction, an[illegible] intercepted by it, and for affording proper communications acr[illegible] remedy of the occupants of neighboring lands to maintain such [illegible] a fit state of repair for the conveyance of water.

This act further provides for compensation in cases [illegible] remission of water rates when allowable, compensation [illegible] the interruption of water supply, and for further cause[illegible]

Part 4 of the act lays down the rules for the levying [illegible] and opens by stating that "such rates shall be leviable f[illegible] supplied for purposes of irrigation, and for any other pu[illegible] from time to time be determined by the governor and co[illegible] cial rates are laid down to be charged where persons us[illegible] thorizedly; also when water is permitted to run to waste [illegible] are made for the obtaining of labor on the canals in ti[illegible] gency, and penalties are provided for damage done to ca[illegible] works.

Land tenures.—In southern India, including Bombay and Madras, while the landholders do not own land, they possess certain rights in it, such as the right to hold and to till it so long as they make payment of part of the produce to the government, while the government possesses the right to a share of the land revenue. In northern India, including the Northwest Provinces, Punjab and Bengal, there is a class of superior landholders between the cultivator and the government. The cultivator tills the land and pays the rent to the landlord, and the latter pays a portion of this to the government. These proprietors are associated together in villages, with an elected or hereditary head, who is responsible to the government for the rent of the entire village. In Bengal there are about 130,000 landlords or heads of estates, who are entitled "zemindars," or may even be rajahs. In the central provinces there are 28,000 separate estates. In the Punjab 1,695 zemindars hold 5 per cent of the total area of that province; 33,020 village communities hold 91 per cent of the total area, and 1,711 other landholders have charge of 4 per cent of the total area. In the Northwest Provinces the area is divided in about the same proportions among the various classes of holders. In southern India, where the cultivators or ryatwari hold the land, it is leased to them for fixed periods of thirty years, though they can resign these holdings at the end of each agricultural year. They can sell or mortgage the land, and at the death of the holder his heirs inherit the right to the lease. In Madras there are 2,392,000 ryatwari or individual tenures on which the average assessment is $5. In Bombay there are 1,367,600 ryatwari.

In these southern presidencies each village is indicated on the revenue map with a defined boundary, and each field is marked out and numbered on the village plan. The different classes of soil are indicated in colors with a description of the class of tenure, marked in a register accompanying each map, in which are also indicated all particulars of soil, tenants, and amount of assessment. The size of the field is determined by the extent of the particular variety of soil which can be cultivated with the assistance of a pair of bullocks. Thus in light, dry soil a field will constitute 20 acres, in heavy dry soil 12 acres, and in rich garden land 4 acres. Some of the circumstances affecting the classification of land and the value of the fields are the position of the latter with respect to the village, the facilities for agricultural operations, the character of the soil, and the opportunities for irrigation.

CHAPTER IV.

EXTENT AND CHARACTER OF IRRIGATION.

CLASSES OF WORKS.

The irrigation works of India are divided by the engineer into two great classes, (1) gravity irrigation and (2) lift irrigation. The former includes four great groups, namely, perennial canals, intermittent canals, periodical canals, and inundation canals. The water supply for these may be supplemented by storage works. These will be treated as a third class.

Perennial canals are taken from the rivers the discharge of which at all times suffices for the irrigation of the lands without the aid of storage. Intermittent canals are taken from intermittent streams, the water of which must be stored in order to furnish a constant supply. Periodical canals are taken from streams having an available supply during the rainy season only, and are used altogether in the cultivation of the summer crop. Inundation canals are taken from rivers having a constant discharge of some magnitude, but are fed by those rivers only when in flood.

Lift irrigation is chiefly illustrated by wells. Of these there is little to say, although the area irrigated by them is considerable. They are used in a country where labor is cheap, and are valuable adjuncts of irrigation, catching the seepage water from the canals and irrigated fields which otherwise would be wasted. Owing to the cost of labor it is doubtful if they will ever be used to any extent in America.

Canals are divided into two great classes, those for irrigation only and those which are also employed for purposes of navigation. The conditions required to develop an irrigation canal are usually, first, that it shall be carried at as high a level as possible, so as to have sufficient fall to irrigate the land to a considerable distance on both sides of it; second, that it shall be fed by some source that will render it a running stream, in order that the loss of the water consumed in irrigation may be constantly replaced in the canal. The chief requirement of a navigable canal, on the contrary, is that it shall be as nearly as possible a still-water canal, so that navigation may be equally easy in both directions, and no water is lost except by evaporation, absorption, and at the points of transfer from the higher to the lower levels. Hence it is most economically constructed at a relatively low level. In India, among the earlier great perennial canals, it was considered the rule to make them navigable as well as irrigable, but since

the introduction of modern modes of transportation, the development of the railway system, and the construction of excellent metaled roads throughout the country, the authorities have generally come to disapprove of the use of irrigable canals for navigable purposes.

EXTENT OF IRRIGATION.

In the presidency of Bombay, exclusive of the Sind, there are 35 irrigation works in operation, of which 3 are major protective works, 7 are major productive works, and the remainder are minor protective and productive works. The total capital outlay on these to end of year 1900–1901 was $9,170,000. The total gross revenue during 1900–1901 was $175,200; the working expenses were $139,000; and the net revenue was $36,200. The area irrigated during that year was 124,972 acres, of which about three-fifths were in autumn or dry-weather crops. The gross revenue assessed was $1.73 per acre, and the water rate averaged $1.33 per acre irrigated. This water rate ranged, however, from 35 cents to $4 per acre, the maximum price being very unusual and due to the large amount of sugar cane which was irrigated on the canal where that rate was levied. The working expenses per mile varied from $70 to $200, and the working expenses per acre irrigated varied from 30 cents to $2. The latter high figures were in both cases charged on the Mutha canal, where a large amount of sugar cane was under cultivation.

In the Sind the net area cropped in 1901 was 1,873,674 acres. The area irrigated from canals was 1,413,487 acres; irrigated from other sources, 362,913 acres; and the total area irrigated was 1,776,400 acres. The area under wet-weather crops was 1,439,869 acres, and under autumn crops about 366,530 acres. The irrigation's share of the net revenue for that year was $1,196,500. The financial statement for the works of the Sind for 1900–1901 was as follows:

Financial statement of Sind Irrigation Works.

Total outlay to date	$7,994,000
Gross revenue during the year	1,071,000
Working expenses	266,000
Net revenue	805,000
Net profit, less simple interest on the borrowed capital	464,000

The average rainfall for all of Sind during the year was 4.98 inches.

In Madras the great irrigation works are constructed in the deltas of the principal rivers. The approximate cost of the works of Madras, without interest, to the year 1899 was $60,225,000; the total area of cultivation due to irrigation was 6,898,839 acres, and the total revenue was $7,722,000.

In Bengal, at the end of 1901, there were in operation 738 miles of main canals, of which 495 miles were navigable; they commanded an area of 2,753,000 acres, of which 1,446,374 acres were actually irrigated. The total capital outlay on the three major works, viz., Midnapore, *Orissa, and Soane canals*, was $27,475,000.

In the Punjab the capital outlay to end of 1901 for major works only was $38,097,000; the total net revenue was $3,333,000, or 8.4 per cent interest on the capital outlay. On inundation works the capital outlay was $777,000, and the interest on this outlay varied from 10.8 per cent as a minimum to 181.5 per cent as a maximum. In this province there were 5,102 miles of main and branch canals and 11,737 miles of distributaries. The working expenses were from 25 to 60 cents per acre irrigated, and the establishment cost from 10 to 25 cents per acre irrigated. The area irrigated during the summer crop was 3,023,737 acres, and during the autumn crop 2,967,814 acres.

The Northwest Provinces, including Oudh, have an area of about 55,000 square miles, of which 30,000 square miles may be said to have been protected by irrigation works at the end of the year 1894. The total outlay on irrigation works in these provinces at the end of 1893 was $27,400,000; the net revenue for that year was $1,270,000, which is 4.6 per cent interest on the capital outlay. The net interest on four principal works—the Upper and Lower Ganges, Agra, and Eastern Jumna canals—was 4.97 per cent. The total working expenses for the same year were $961,000. There were in operation 1,427 miles of main and branch canals and 6,748 miles of distributaries. The total area under irrigation was 1,799,866 acres, of which 706,221 acres were summer crops and 1,093,645 acres were autumn crops. The value of the principal crops was $10 per acre.

FINANCIAL AND AGRICULTURAL RESULTS.

Of major productive works, the capital for which has been provided from borrowed money, there are 35 in the six principal provinces. The capital expended on these works to the year 1900 was about $100,000,000, while the sanctioned estimates for the completed projects were $103,572,000. These 35 major works are designed to irrigate, when fully completed and irrigation has been fully developed, something more than 10,356,000 acres. Of 6,000 miles of main and branch canals no less than 2,300 miles are navigable. The cost of making these canals navigable can not be readily ascertained, but should be eliminated in determining the true cost of each irrigable acre. The Mutha canal, in Bombay, which is the most expensive of any canal of its kind, derives a considerable income from the supply of water for domestic purposes to the city of Poona. It may be said that the works of this class average $9.30 for each acre irrigable. Of the 10 largest of these major works, the most expensive, the Orissa system in Bengal, cost $27 per acre, and the Ganges canal, which covers the largest area of all, and is at the same time the cheapest, cost a little under $6.30 per acre.[a]

In addition to the 6,000 miles of main canals constructed in these 35 systems, there are 18,000 miles of principal distributaries. Up to

[a] *Buckley*, R. B., Irrigation Works in India and Egypt, London, 1893, pp. 283-284.

the present time only 12 of the 35 major productive works have been worked at a profit of more than 4 per cent, but the profit from these 12 has been more than sufficient to cover the deficiencies of the other 23. The net result is that the works of this class have covered the interest charges, with a gross excess to the government of nearly $12,642,000.

For the first twenty years these modern British works were not altogether profitable. During the past ten years, however, since nearly all have been in full operation, the net revenue return for the 35 works together has averaged more than 4 per cent per annum on the $100,000,000 gross capital outlay.

Among the six provinces in which this class of work lies, Madras and Sind are preeminent as those in which all the works have been in operation for more than ten years and are thoroughly successful. In the Northwest Provinces all four works are now thoroughly successful, paying over 5 per cent net revenue, and in the Punjab there is little doubt that all of the works will finally be successful, while the older ones already pay well. One of the youngest works, the Sidhnai canal, is very remarkable in having paid nearly 14 per cent on its capital during the second year it was in operation. Of the Bengal works little hope can be entertained, as the normal rainfall there is too large and too regular to make irrigation an urgent requirement for agricultural prosperity. These works must be looked on as a protection against occasional drought and famine rather than as a source of profit.

Of major protective works there were in operation in 1900 in the six principal provinces 5 works, the capital expenditure on which was $6,866,000. These works are designed to irrigate 723,720 acres, at an average capital cost of nearly $8 per acre. There are completed in these systems 400 miles of canals and 800 miles of main distributaries.

Of minor works the capital of which has been provided from the general revenues of India about 80 were in operation in 1900, distributed throughout nine provinces, including Burma and Beluchistan. The capital expended on these works was $15,040,000 and the net revenue was $737,000. The percentage of net revenue on the total capital outlay to the end of the year under consideration averaged nearly 5 per cent, and varied from naught in the case of some works in Bombay to 16 per cent in some of the works of Burma and 24 per cent in some inundation canals in the Sind. These works comprise altogether 6,500 miles of canals, 2,650 miles of distributaries, and render irrigable an area of about 7,201,578 acres. The works of this class taken collectively are more remunerative than the major productive works, which were specially constructed to pay nearly 5 per cent. The numerous small works in Bombay are unproductive, and there is but little hope that the returns derived from them will materially improve.

In 1900 there were irrigated by major productive works 11,409,528 acres. The rate of working expenses per acre on a classes of works varied between 40 cents and $2.60. The gros irrigated by all three classes of works was 18,611,106 acres, whi entire area under irrigation, including that watered by wells an double cropped, was 33,096,031 acres. The average water rate ch was less than $1.40 per acre. The average value of crops pe varied from $10 to $35, and the percentage of rate charged value of the crop was between $3.30 and $8.25. Gaged by the ard of the percentage of rates charged, theoretically the gage severity of the charge on the cultivator, the Bombay rates, whi actually the highest, are shown to be the lowest, and this is rea fact because of the very high value of the sugar-cane crop so sively cultivated in that province. The gross value of the cro gated in 1900 by all the four classes of irrigation works admini by the government reached the sum of $155,000,000.

At a moderate compensation it may be said that one-half sum is the increased value of the outturn from the fields due gation from the canals. This figure shows perhaps more readil any other the value of the agricultural interests which are bou with irrigation works of India.

The agricultural results of Indian irrigation, and an idea of t and returns of building and operating canals can best be obtai citation of the results on a typical perennial canal, as the Sirhind in the Punjab. In 1900–1901 the amount and value of the pri crops irrigated on the British branches only of this canal are as fo

Crops irrigated on Sirhind canal in 1900–1901.

	Value.
Barley	$124,000
Maize	641,000
Wheat	1,247,000
Mixed grains	176,000
Cotton	101,000
Sugar cane	293,000
Millet and pulses	1,781,000
Fodder crops	428,000
Vegetables	222,000
Oil seeds	117,000

It will be interesting to examine the items of cost, interest, an enue of such a canal as this, and to make comparisons between costs and returns and what might be derived from a similar w

made in the United States. In making this comparison the amounts reported in the revenue returns for such expenditures as pensions, furloughs, and navigation works must be deducted from the total outlay and due allowance made for the difference in cost for each class of construction in the two countries and for the water rate to be charged. To the end of 1901 the total expenditure on the Sirhind canal was $19,663,000, of which $6,749,000 was interest while the work was under construction, and $1,000,000 was leave and pension allowance to employees.

Though such a work would have been constructed in a much shorter time in the United States, owing to the substitution of mechanical means for hand labor, the rates paid in our country for interest would probably equalize this charge. The total original cost of the works was $12,000,000, of which, exclusive of the cost of land and maintenance, $400,000 was for head-works, $6,500,000 for the main canal and branches, and $1,100,000 for right of way and navigation works. The office establishment in India is an expensive one and, less pensions, costs $2,200,000, while the tools and plant cost an additional $1,100,000. In the main canal and main branches the earthwork alone cost $2,600,000, and on the distributaries this item cost $800,000, making $3,400,000 for earthworks.

For the total 1,170,000 acres of irrigable land controlled by the Sirhind canal the cost for earthwork was $4.25 per acre. Our contract prices in the West being, say, 10 cents per cubic yard against their 4 cents, this earthwork would have cost us $10.62 per acre. The masonry works—as falls, weirs, regulators, and bridges—cost in all $2,400,000, or $3 per acre irrigated. In India rubble masonry costs about $3 per cubic yard. In our West it averages, say, $6. Hence these works would have cost us $6 per acre. In our works, however, we would avoid the expense of the numerous masonry bridges constructed in India; again, we would do comparatively little masonry work, but would use iron and wood, which are relatively far cheaper. The cost for these items would accordingly be proportionately less. Perhaps one-third can be deducted for the cheaper material, and it would cost us, therefore, $4 per acre irrigated. The drainage works and escapes cost about 73 cents per acre more, or such a work as the Sirhind canal would have cost $15.35 per acre irrigated against $8 in India.

Owing to the recent completion of the Sirhind canal it irrigates at present only 1,170,000 acres. This, however, paid in 1900–01 a surplus revenue, after paying interest on the capital outlay, of 4.7 per cent per annum, and of 9.1 per cent net revenue on that outlay. The water rates charged averaged 90 cents per acre irrigated. We could charge at least $2, and in some localities more. As the cost of construction in America would be twice that of India, while the receipts per acre would be nearly three times as great, it is not improbable that under similar circumstances such a work when fully utilized would yield

from 5 to 12 per cent, and when doing its maximum duty would realize as a minimum 10 per cent on the capital invested.

In addition to the amount realized from such a work as compared directly with that obtained in India, there is one source of revenue in our country which does not exist in India. That is the annual increase in value of the land served by the canal. There is no such increment available to private enterprise in India, because the Government is the owner of the land. In America, however, where land can be purchased at from $1.25 to $2.50 per acre, and when supplied with water right will sell for from $40 to $100 per acre or bring an equivalent revenue, the increased return from such an investment is obvious.

CHAPTER V.

ALKALI AND DUTY.

OBJECTIONS TO IRRIGATION.

In 1845, during surveys for the great Ganges canal project, a committee was appointed, under instructions from the governor-general f India, for the purpose of reporting on the causes of unhealthfulness which existed along the line of the Delhi canal, and ascertaining 'hether injurious effects on the health of the people were likely to be roduced by the contemplated Ganges canal. Their report is one of ıe most complete and exhaustive ever prepared relative to the effects f canal irrigation on the health of the neighborhoods irrigated. The ıembers of the committee were Maj. W. E. Baker, R. E., president; ırg. T. E. Dempster, and Lieut. H. Yule.[a]

Among the more important conclusions reached were:

(1) That in considerable portions of the district under the influence existing canals sickness has been largely developed.

(2) That this sickness is not attributable to the results of irrigation ıt to the canal works or water courses of private individuals having tercepted the natural drainage of the country, and having thus led the formation of swampy tracts diffusing malarious influence around em.

(3) That where the soil is light and the irrigation carried on by eans of main distribution channels, all the advantages of canal irriıtion may be gained without the prevalence of any of those evils to ı found in localities differently constituted.

(4) That if care is taken to irrigate only that land which has an open il and which has such slope and low drainage lines as to prevent ıter-logging, no unhealthy results will follow irrigation.

(5) That irrigation with free surface drainage may be regarded as ıite innocuous.

(6) That when malarious influences are developed by irrigation eir effects are almost strictly local.

This committee recommended that the Ganges canal be kept as much possible within soil, that is, that its ordinary surface level should be ılow that of the country. That earth wanted to complete embankents be never obtained from excavations made outside the canal ccept from such localities as would readily admit of drainage. That e canal and its branches be taken as much as possible along the

[a] Cautley, Col. Sir Proby T., The Ganges Canal, London, 1860, vol. 3, p. 24.

watershed of the country, so as not to interfere with drainage, and that irrigation be prohibited in localities which appear to possess naturally a malarious character.

On this same subject Capt. Douglas Galton, of the army sanitary commission, wrote an interesting article[a] in which he gives several instances where localities that have been sandy deserts devoid of vegetation had by means of irrigation been converted into rich grain fields. For many years the irrigation measures have not been attended by any effects prejudicial to health. The subsurface water had been, however, gradually rising nearer to the surface, and at the same time fever had greatly increased. In Madras, where during drought little fever prevailed, during the southwest monsoons large districts were flooded and fevers became prevalent. It was observed in the Punjab that the fever appeared not to have been generated so much during heavy rains as from the conditions which follow them, and the remedy required is the rapid removal of water to prevent stagnation. In almost all low-lying tracts saturated with moisture the people were fever-stricken. Captain Galton sums up by saying: "The whole evidence shows the high fever death rate to be largely due to the stagnating water in the soil." The objections on the score of health are, generally, defective drainage, the stagnation of the water, the deterioration of well water by infiltration, or the application of too much water. These are all remediable and within the control of the engineer.

On the line of the Mutha canals in Bombay, where sugar cane is extensively cultivated, it is found that the stagnating waters retained by the roots of the plants are producing fevers, and as a consequence the government is endeavoring to reduce the area under sugar cane, hoping thus to reduce the extent of the fever. In the Northwest Provinces regular observations are made of the height of the spring level, and these are submitted annually with the revenue reports, thus indicating by the rise of this level the necessity for artificial drainage works to prevent supersaturation of the soil.

Another of the more important ill effects of irrigation is the production of alkali, or the efflorescence of alkaline salts on the surface of lands irrigated. That the effect of irrigation, however, is not altogether bad in this respect may be surmised from the following remarks made before the famine commission by Major Grey, C. S. I.:[b]

> Canal irrigation has rendered fit for cultivation large tracts in the Bahalpur State which were utterly unculturable because of alkali, and that when heavily irrigated the salts were washed off or driven into the soil.

Mr. E. O'Brien testified to practically the same effect, and stated that if properly effected canal irrigation is a cure for efflorescence. Mr. E. C. Corbin found that on lands covered by efflorescent salts

[a] Galton, Capt. Douglas, Sanitary Progress in India: Journal of the Society of Arts, London, 1876, vol. 24, p. 526.

[b] *Report of Famine Commission*, London, 1881, Appendix V, p. 4.

canal water has eradicated the evil of alkalinity, and that land before worthless is now highly productive.

In all probability the most valuable report on the effects and causes of alkalinity was that made by the "Reh" (alkali) commission for the Aligarh district of northern India, of which Mr. H. S. Reid was president, and among the members of which were Mr. Medlicott, the superintendent of the geological survey of India, Mr. Burch, the director of agriculture and commerce, and others. This report was printed in full by Prof. E. W. Hilgard,[a] of the University of California, and its substance is as follows:

Tracts rendered unculturable by excess of alkali exist more or less throughout the Northwest Provinces of India, but it is due to the introduction of extensive irrigation works that no appreciable increase of the area of alkali lands is perceptible. In the earlier of these irrigation works no provision for drainage was made, and they were simply built for the purpose of affording an abundance of irrigation water. Gradually, however, it was noted that crops began to languish and that the lower lands were rapidly being converted into swamps, while on the higher lands alkali spots were rapidly enlarging, while new spots were being formed where none had previously been known. The cause was apparent, and there was no difference of opinion regarding it. Not only near but within even considerable distance from the canals the subsoil water level has been raised from a depth of 50 feet to within a few feet of the surface. This subsurface water has brought up with it by a leaching process all the alkali salts existing within the subsoil thus traversed, and by evaporation these salts were diffused throughout the many feet of substrata, accumulating at the surface to such an extent as to render cultivation unprofitable and even to make the soil absolutely barren, covering it with a white crust of salt. While the committee agree that the most damage has been brought about by the rise of this subsurface water by the sidewise soakage from the high-lying canals, they state that the trouble has been greatly aggravated by the extravagant use of water by the peasants. The remedies suggested are as follows:

First, a deepening of the two canals so as to lower their water levels, and hence that of the soakage subsurface level, at least several feet below that of the land to be irrigated. Secondly, they recommend the establishment of a system of drainage. It unfortunately happens that both of these measures frequently offer great engineering difficulties in a region where, from the scantiness of rainfall, the surface conformation of the country is not favorably sculptured.

The investigations of the committee all point in one direction, viz, that the introduction of canal irrigation is the principal cause of alkali extension, and that when the removal of soakage water takes

[a] College of Agriculture, Appendix 7, Report of 1886, Sacramento, 1886, p. 34.

place almost exclusively by evaporation, irrigation by canals must end in a destructive crop of alkali where the indigenous resources of the ground in that way were comparatively harmless. *As a remedy the members of the committee almost unanimously proposed deep drainage*, and great importance was attached to keeping the natural drainage of the country open. No dams or cultivation should be allowed in the natural drainage courses, and the more water that can be gotten to flow away from the canal tracts the better, while any alkali that it may carry away in solution is so far a gain. The committee agreed that the lavish use of canal water which the gravity-flow system encouraged caused extensive saturation of the soil. As a résumé of the evil effects of irrigation it becomes apparent that they are almost all produced by a wasteful use of water and careless alignment of canals, advantage not being taken of the natural drainage of the country, together with careless irrigation of those portions of the country which are too low to afford natural drainage. It is apparent that alkalinity, once fairly developed, can never be cured under existing conditions of water level, and the same is doubtless true of malarious fevers. The primary conditions of alkalinity and fever may be expressed as defective water circulation, though mere surface drainage is ineffectual for the removal of alkali.

Relative to double cropping the soil the chief engineer of the Punjab said in his report for 1889:

> The area double cropped on the Bari Doab canal was 14.1 per cent of the whole area and nearly one-fourth of the autumn crop. It seems to be slowly increasing, which is not satisfactory, as the practice is generally detrimental and exhausting to the soil.

Similar opinions have been expressed by other engineers, and the practice of double cropping is not encouraged unless accompanied by the free use of fertilizers.

Regarding the effect of irrigation on the navigation of rivers and its effect on riparian rights, Col. Baird Smith states:[a]

> At the head of the Jumna canals the Jumna River carries at low season, during four months, a minimum of 3,500 second-feet. The canals use 3,000 second-feet, leaving the river bed practically dry. At Agra, which is about 303 miles lower down the same river, the Jumna carried at the same period about 3,500 second-feet and is an unfordable stream.

This supply is derived from subsurface drainage and seepage from canals, so that the canals have not in the least affected navigation. The Ganges River at Hardwar carries at least 8,000 second-feet, of which 6,700 second-feet may be abstracted by the canal. Still, at Narora, lower down on the same stream, and the head of the Lower Ganges canal, the stream is large enough to admit of 2,000 second-feet being taken by that canal without affecting navigation.

[a] Irrigation in Italy, London, 1856, vol. 1, p. 385.

WATER DUTY AND EVAPORATION.

In discussing the source of supply the engineer has to determine the quantity of water required and the area of irrigable land. It is then necessary to determine the "duty of water" for the crops to be irrigated, the qualtity of the soil, and the loss to be anticipated from evaporation and absorption.

The "duty of water" is an expression which is used in India, as in the United States, to indicate the area of land which a fixed unit of water will irrigate, and, as in America, the unit adopted is 1 cubic foot per second of flow, or, as we express it, 1 "second-foot." In referring to the contents of reservoirs the Indian engineers usually quote them as holding so many cubic feet of water, but owing to the difficulty in dealing with the billions of cubic feet which a large reservoir will store, I prefer to use the American unit "acre-foot," by which is meant a quantity of water necessary to cover an acre 1 foot in depth, or 43,560 cubic feet. In designing canals in India the expenditure is frequently reckoned per linear mile of canal, and this has been found to be generally from 6 to 8 cubic feet per mile. Such a method of computation is possible only when the main and branch lines of canals have been previously determined, as it enables the engineer to regulate the cross sections of the canal along its entire length, diminishing the same as the water is expended.

The duty of water differs greatly with different soils and crops, and has usually to be determined by the engineer for each locality. The following results indicate the variability of duty as discovered in India. On the Mutha canals, near Poona in Bombay, the duty of water in 1888, during the autumn season of four months, was as follows: Wheat required 2.18 acre-feet per acre irrigated, or the water performed a duty of 170 acres per second-foot. Sugar cane, however, required 19 acre-feet per acre irrigated, the water performing a duty of 43 acres per second-foot.

Sir P. T. Cautley, from results obtained experimentally on the Delhi and the Doab canals in 1845, discovered that for that region 800 second-feet constant discharge was a fair irrigation supply for 100 miles in length of canal, assuming that a district having an area on each side of the canal from 4 to 5 miles wide would be irrigated. On each 100 miles he discovered that the canal would irrigate 237.4 square miles, and allowing that only one-third of the area controlled was irrigated, the above supply would suffice for 820 square miles.

Before proceeding to a further consideration of the duty of water, it will perhaps be well to examine some of the theories regarding its determination. The following remarks are liberally quoted from an extremely interesting investigation of this subject made by Mr. J. S. Beresford,[a] executive engineer in the irrigation branch of the Indian public works department, Northwest Provinces.

---

[a] Memorandum *on the Irrigation* Duty of Water: Roorkee Professional Papers, No. 212, 1875.

Theoretically, 1 cubic foot of water running for a month will c an area of 60 acres to a depth of 1 foot. It is generally held t inches is a safe allowance for one watering. Mr. Beresford is o opinion, however, that more than 2 or 3 inches is rarely given. In to determine the depth of moistened soil, the following experi was made on July 25, when a fall of 5.5 inches of rain was gag the Mankri station. About five hours after the cessation of this fall the field examined was covered with a film of water averagin inches in depth. Several holes were dug, and the depth of moist soil was found to be from 16 to 18 inches. In other fields near by from surface water, the depth was from 12 to 18 inches—that i minus 1.5, or 4 inches of water will moisten ordinary loam to a d of from 16 to 18 inches. A few days previously holes had bee in irrigated fields of the same soil that had been recently watered the depth of moistened earth was found to be from 11 to 12 in On the 30th the 1.5 inches of standing water had disappeared more holes were dug; one in a low place, the other where the gr seemed a few inches higher. The depth of water in the forme 34 inches, in the latter 18 inches. The conclusion reached wa the ground absorbed the rain uniformly everywhere up to a fall inches in ten hours, the duration of the storm referred to. Wha in excess accumulated in low places and soaked those to a greater depth.

Not a drop of rain had fallen before the 25th of July except fraction of an inch on the 5th and 9th, which softened the gr sufficiently for plowing. Allowing 4 inches as the depth require one watering, and that in the hottest weather, this is given only a month—for if watered oftener a proportionately less quantity suffice—the theoretical duty of 1 second-foot of water is 180 ac the summer months. In the autumn, however, crops are rarely more than two waterings, many only one, and the theoretical during the autumn season, allowing the watering to be lighter in the summer and probably about as frequent, ought to be 320 a or the theoretical duty in the locality examined should, for the be 500 acres.

The actual duty obtained on the best divisions of the Ganges in the neighborhood under examination is not over 160 to 180 per second-foot, or about one-third of the assumed theoretical There are sufficient statistics to show what the actual duty is. next important thing is to make the theoretical and actual approach as closely as practicable. Considering the Ganges can a great machine, its principal parts are the main canal, the dist taries, the village water courses, and the cultivator who applie water. Each cubic foot entering the head is expended principal follows:

(1) In waste by absorption and evaporation in the main c

(2) In waste from the same causes in the distributaries and in the village water courses. (3) In waste through carelessness of the cultivators in not distributing the water evenly, or in allowing the ground to get saturated to an unnecessary depth. (4) In useful irrigation of the land. The object is plainly to increase the last by reduction of waste through all the rest.

From a consideration of the actual duty obtained by various experiments as compared with the theoretical duty Mr. Beresford shows that the efficiency of the canal under consideration is sometimes as low as 25 per cent. The next point established by him is the nature of the waste called absorption and evaporation, and what proportion is due to each. This discussion is extremely interesting. The loss by evaporation is the first considered. Taking a distributary 30 miles long with a water surface averaging 10 feet wide, the loss by evapora-

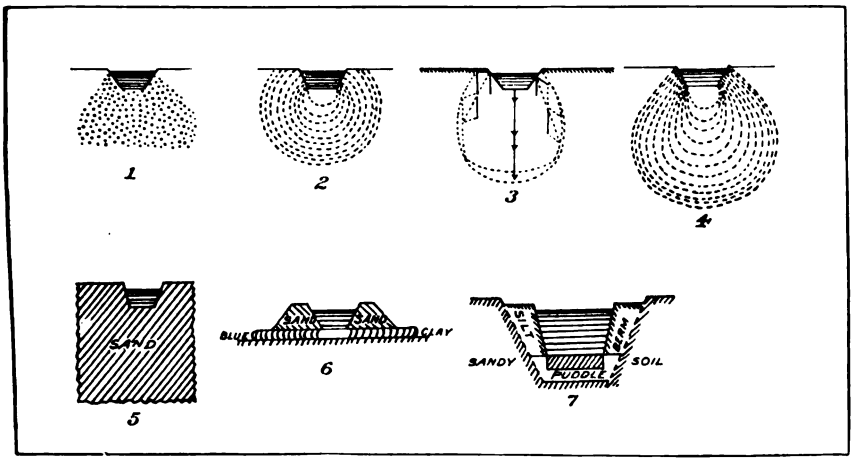


FIG. 1.—Percolation and evaporation.

tion per second in this length of water course would be 0.8 of a cubic foot by computation, and assuming that the area of water surface in the village channels equals twice the surface in a mile of the distributary, the loss by evaporation in all the village channels would be 1.6 cubic feet, or the whole loss by evaporation on the distributary 30 miles long with its minor water courses would be over 2.5 second-feet, or about 5 per cent of the probable discharge. From this we see that evaporation is not of so much consequence as far as the different channels are concerned even in the hottest weather, and may be neglected in the autumn season. The chief loss must therefore be due to percolation and absorption. The former may be said to be due to cultivation, the latter to capillary attraction.

With the aid of the accompanying illustrations (fig. 1) the following discussion will be readily appreciated. Absorption is a more complicated process than percolation. The latter takes place in bowlders

coarse gravel in a manner similar to that by which water issues through pipes or strainers in the bottom of a vessel, and the quantity discharged per second will depend on the size of the interstices of the stones, their number, the head of the water, etc. The thicker the bank through which the water is escaping, the longer and more broken the channels of escape will be and the greater the friction; but the question of discharge depends on the same principles as does the discharge through pipes. If the gravel is considered to be broken into very fine sand and the embankment formed of this material, the principles of discharge are quite changed. The interstices are now very small and act in the same manner as do capillary tubes. If empty the water rushes in and fills the cavities, and if the particles are sufficiently fine they are rammed close together, and the embankment is of a certain width, the water is retained in the cavities with greater force than that due to the hydrostatic head pressing it through. The force that thus retains the water is termed capillarity, and, although it may in reality be the same thing as gravitation, it may in this discussion be considered as quite a separate force.

Fig. 1, No. 1, represents a channel in a gravel soil or one composed of coarse sand, and the dots indicate the manner in which the water would trickle through the ground. No. 2 represents what would probably take place if the action of gravity were suspended and only absorption brought to play in a homogeneous soil. But gravity, which is always in play, modifies this capillary action, and the water has actually to follow the resultant of two forces. No. 3 explains this action, where the straight lines and their resultants indicate the distance to which capillarity and gravity alone and combined will carry the particles of water, and the result would be as shown in No. 4.

That absorption does not make itself more visible in high embankments is due to two reasons, the first being that the soil in low places is much more clayey than elsewhere, and there only are high embankments constructed, and the second that absorption ceases when the absorbing medium is limited. In an embanked channel the absorbing medium immediately stops at the outer slope, and only what has evaporated is made good by absorption. If we dig a hole in a bank of sandy soil, as represented in No. 5, and the hole be filled with water, this will dry up in a few moments, but if a layer of clay is spread on the ground, as in No. 6, and an inclosure made with the same sandy soil rammed as a natural bank and filled with water, the latter will not decrease beyond what the banks at first absorb. In the first instance the absorbing medium is unlimited; in the second it is limited to the soil in the embankment. It is for this reason alone that sandy embankments can dam up water at all. A very interesting experiment suggested by Mr. Beresford well illustrates this action. Take a bottle and close the mouth tightly with a small piece of sponge. If the bottle is then turned upside down, the sponge will become sat-

wated, but unless pressed by the finger will give out no water. If another large, dry sponge is placed in contact with it, the water at once begins to flow through the sponge in the neck of the bottle, and this continues until the second sponge can absorb no more.

We may fairly conclude that it is the layer next the wetted perimeter that limits the quantity absorbed; that the greater its area the more it will pass through to the still greater area of the next layer. Everything being equal, we may say that absorption varies as the wetted perimeter. Hence, for sections of canals of small length we may take the loss as being so much per mile, but in general the discharge and wetted perimeter decrease with the length, but the latter not nearly in the same proportion as the former. Thus the loss up to any point may be found when the loss between two other points is found. The total loss up to any point is the loss in the first mile multiplied by some function of the length. This, in some cases, has been found equal to five-sixths.

Mr. Beresford next enters into an interesting computation in which the efficiencies of the various causes of waste are considered as algebraic factors with the numerical values determined as above, while the efficiency of the cultivator, which varies within wide limits, is taken as being between 0.5 and 0.9, where unity represents his efficiency at the theoretical limit. He finds the loss from percolation to be 1.25 cubic feet in the first mile, and in long lengths of canal about a quarter of a cubic foot per mile. The final result obtained indicates that for each cubic foot entering the distributary only 0.68 is available for fields beyond the tenth mile.

The remedies heretofore applied to lessen these defects have been few. The distributary of to-day is the same as that of thirty years ago, so far as construction of channel is concerned. The minor water courses are rarely constructed or attended by an engineer, and as a rule are badly aligned and constructed and not maintained. The cultivator is the only part of the machine which has been improved. Mr. Beresford is of the opinion that the widest field for improvement is in the minor water courses. The same applies to the private irrigating channels of the farmer of our own West. These minor channels are certainly on an average 25 per cent longer than need be. They even run a long distance through sandy ground, which absorbs a great proportion of water. The size of discharge of the module or regulator is frequently not suited to the length or conditions of the water course; and two different water courses sometimes run side by side, thus increasing the wetted perimeter and the consequent loss. The first recommendation made by Mr. Beresford is in all cases the construction of a good map. This is desired by all canal engineers, but it is rarely made, because it is thought to mean an endless amount of surveying. The saving from the construction of such a map would be more than paid for in the saving of water. It is rec-

ommended that all small water courses be puddled when running through sandy soil. A layer 3 inches thick (fig. 1, No. 7) would suffice. If the cost of this was as much as $100 per mile it would not be exorbitant, for in the length of a mile, if the discharge at the head is 1 second-foot and the loss 25 per cent, the saving effected would increase the duty by from 20 to 40 acres.

The losses in distributaries, although proportionately less than in the minor channels, are often large, especially in new channels. The particles of sand or silt carried in suspension are usually dropped in the upper reach, but particles of clay or very fine sand are carried to the very tail and are often deposited on the sides and bed to a considerable thickness, forming a more or less impervious lining or silt berm. The deposit on the bed, even a long way down, is more charged with sand than is the berm. The sand being heavier, drops to the ground, and as it is rolled along picks up the lighter particles of clay. It is not recommended that the sides of the distributaries be puddled unless in the first few miles, but the bed in sandy soil might be advantageously puddled everywhere to a thickness of several inches. A temporary measure suggested by Mr. Beresford is to collect clay and, breaking it into fine particles, throw it in near the canal head or at the falls, when the action of the water will thoroughly break up the clay and carry it into the berms and water courses miles below, thus rendering them impervious.

In 1867 Mr. E. C. Palmer, executive engineer of the irrigation works, Northwest Provinces, made some interesting experiments in the same direction on the Bari Doab canal.[a] Among other experiments conducted, one was made to determine the time required to saturate thoroughly an acre of ground. In these experiments the discharge orifices were 15 feet in length, each of the same dimensions and working under the same heads. The experiments were repeated on different varieties of land. It was found that an average depth of 3 inches of water on the whole surface represents a thorough watering on average soil. In sandy soil it was as much as 4 inches. This gives 10,454 cubic feet, or about one-fourth acre-foot, as the volume required to water 1 acre. In ordinary soil the average is actually a little over 0.2 of a foot, or 9,150 cubic feet. In these experiments the quantity of water varied, according to the soil and other circumstances, between 9,000 and 14,500 cubic feet per acre for one watering, and the time required to water an acre varied from two to twelve hours. In the dry season wheat required four waterings and 10,500 cubic feet of water. For the first watering, in order to prepare the ground for plowing and sowing, 8,000 cubic feet were required, and the same amount for each of the remaining four waterings on the standing crop. An acre of wheat, therefore, required 42,500 cubic feet to mature the crop, or nearly an acre-foot of water per acre. At the prices then current the cost to the

[a] Palmer, E. C., Irrigation Experiments: Roorkee Professional Papers, No. 35.

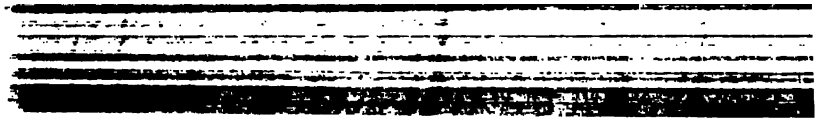
State was 75 cents per acre and the water rate derived was $1.60 per acre. The time required to cover an acre of land was 0.445 day, or 2.2 acres per day. For standing crops the rate is about 4.4 acres per day, as they ordinarily require not more than half as much water as is necessary for plowing.

The losses by evaporation and absorption and the duty of water are now well known in India on the various lines of canal and for the numerous reservoirs that have been in operation for many years. In the Northwest Provinces the duty of water for the year 1888 varied, for different crops, from 120 to 194 acres per second-foot, and the money value was from $143 to $286 per second-foot. From experiments conducted on the Betwa canal in the same province it appears that mixed sugar-cane and indigo crops (which need much water) required a total volume in eighty days of 310,000 cubic feet per acre for wet-weather crops, while the autumn crops required 150,000 cubic feet, or about 3⅓ acre-feet per acre. In some experiments made on the Nira canal to ascertain the amount of wheat which could be irrigated in a given period of time, it was found that with a second-foot of flow 8 acres of wheat could be irrigated in twenty-four hours.

In estimating the supply of water necessary to irrigate a given area of land it has been found from actual experiment that a large proportion of the land covered by any given irrigation system is always unirrigated and that water need only be provided for a certain small percentage of the total area of irrigable land. This land is not irrigated for several reasons. It may be occupied with buildings or roads or be in use as pasturage. A certain proportion receives water by seepage from adjacent irrigated fields, and another portion is occupied by towns and villages. In drawing up the projects of the great canals in the northwest it was found by data derived from experience on the Jumna canals that each second-foot of discharge was capable of irrigating 218 acres, and it was reckoned that for each acre irrigated there would be 2 other acres unwatered. Hence each second-foot represented a duty of 654 acres, or approximately 1 square mile. In drawing up the project for the Soane canals in Bengal Colonel Dickens reckoned three-quarters of a second-foot to every square mile of gross area. To date the Soane canals have been in operation fifteen years, and yet there is a demand now for not over 100 acres in 640, and the system of distributaries as designed for these canals has proved to be unnecessarily elaborate. In the Punjab it is customary to design works to irrigate only from 20 to 30 per cent of the area covered, and where water for more is demanded it is usually not given, as it is bad for the land, producing water-logging and its consequent evils. The experiments made on the eastern Jumna canal in 1845 showed that on the Saharanpur division one-fifth only of the total area cultivated was actually watered, and on the two other principal divisions the percentages were one-fourth and one-third, respectively. A similar

experiment conducted the same year on the western Jumna canal showed that of the total area cultivated from one-half to one-third only was actually watered.

In gaging the velocity of discharge of rivers in India floats are usually employed. In some of the great rivers where there are weirs constructed the depth of water passing over these weirs gives a measure of the volume of discharge; in a few cases only are current meters used. In the canals the discharge is almost invariably obtained by means of wooden floats, sometimes floating on the surface and sometimes submerged. These are timed for given distances, usually marked out in an aqueduct or other portions of the channel where permanent gage rods are established. On the minor distributaries V-shaped weirs are in general use for the measurement of discharge.



CHAPTER VI.

WELLS AND INUNDATION AND DELTAIC CANALS.

WELLS.

As before stated in classifying the irrigation works, lift irrigation m wells is extensively practiced throughout India. Wells are eco- nically among the most important irrigation works in India, because y are the most general. They vary in depth from 10 to 60 feet, l may be unlined if shallow, lined with stone dry-packed, or with sonry.

The modes of lifting water from wells are of different kinds, viz, by ans of a bucket raised by a well-sweep and called the paecottah, ensively used in Bengal; by means of a mot, whereby a leathern ; is raised from the well by bullocks walking away with a rope— nethod that is practiced most extensively in the Northwest Prov- es, in central India, and Bombay—and lastly, by means of the rsian wheel (Pl. IV, *A*), employed chiefly in the Punjab. As an lication of the extent to which wells are employed in irrigation, we d in the Central Provinces 650,000 acres irrigated from tanks, while),000 acres are irrigated from wells. In Madras there are 31,000,000 es under cultivation, of which 5,320,000 acres are irrigated by nals and tanks, and 2,000,000 acres by 400,000 wells. In the North- st Provinces in 1888 the area irrigated by wells was 358,600 acres, 23.6 per cent of the whole area under cultivation. In Coimbatore ere are said to be 100,000 wells sunk, in many cases through hard k, to a depth of 80 or 90 feet, and capable in ordinary seasons of igating from 1 to 4 acres each. As a contrast with the utility of nal or tank irrigation it has been estimated that the Ganges Canal ne replaces the work of 300,000 men and 1,300,000 bullocks, besides reasing the value of crops irrigated by wells by 50 per cent.

The paecottah of southern India, also called the lât in upper India in Egypt the shadouf (fig. 2), is usually worked by two men who or from six to eight hours daily. Authorities estimate that they l raise from 400 to 2,000 cubic feet per second per day. From derate depths three men working two paecottahs will water three es a season. The mot (fig. 4) is a leathern bucket made of a whole nide, and is raised by two bullocks walking down an incline and wing after them the rope attached to it. When the bucket reaches

the surface it is emptied automatically or by an attendant. In Bombay the bullocks usually return by walking backward; elsewhere they are not trained to do this, and they face about to return (Pl. III). Sometimes two yoke of oxen are used hitched alternately to the rope.

FIG. 2.—Paecottah.

From the Calcutta Engineers' Journal it appears that two bullo working ten hours a day for a season of ninety days will raise w the mot 162,000 cubic feet of water, or about 3¾ acre-feet.

The Persian wheel (fig. 3) consists of a large wheel revolving ve cally in a shallow well. On its outer periphery are a large numbe

A. PERSIAN WHEEL.

B. PAECOTTAH.

buckets. These lift the water and empty it into a trough, ce it runs into the ditches. The wheel is made to revolve by

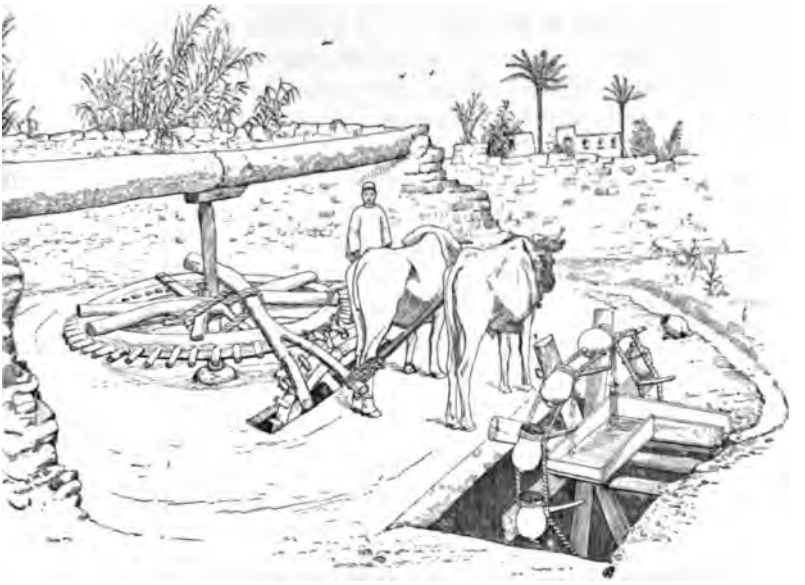


FIG. 3.—Persian wheel.

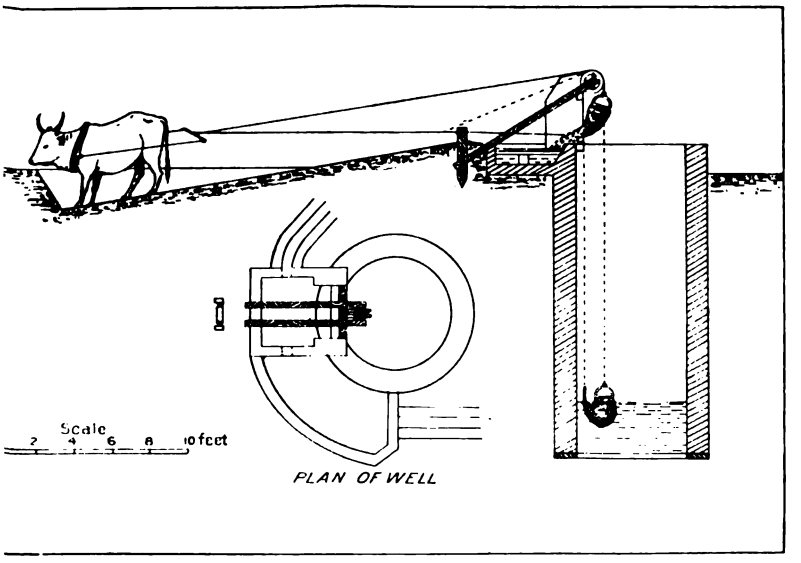


FIG. 4.—Single mot.

is of a cogged gearing and is turned by two bullocks walking in le and hitched to a horizontal sweep. By this method it is esti- d that 2,000 cubic feet of water may be raised per day.

INUNDATION CANALS.

The inundation canals of India have been constructed and are chiefly used in the valley of the Indus, and as they have no permanent head-works they depend for their utility on two conditions generally absent in the United States. First, the stream from which an inundation canal is taken must flow at a high elevation relative to the surface of the surrounding country; that is, its bed must be practically on the summit of a ridge, as is the case with the lower Sacramento and Mississippi rivers. Second, the river must be subject to great annual floods lasting through a long period. Inundation works have been among the most profitable canals operated in India, chiefly because of their simplicity of construction. As a general thing the inundation canals diverted from the rivers of the Punjab and Sind are used to irrigate the lowlands only. Cuts are made from the river inland for a certain distance, thence the canal line follows the general slope of the country. By these canals the autumn crop is watered when the river is in flood. Large quantities of silt are left in the beds of the canals or heaped up at their mouths, varying from 1 to 8 feet in depth, and this is cleaned out during the cold season. From the main canal the water is distributed to the fields by branch canals and minor channels in a mode similar to that employed in irrigating from other canals.

There are no works at the heads of inundation canals to control the supply of water. They are constructed on rivers whose courses are so uncertain that they may at any time desert the head, when the water will have to be brought into the canal by a new mouth excavated the next season. Under any circumstances the deposit of silt at the head is considerable and would naturally be increased by anything in the shape of a dam. The labor in clearing the silt is a heavy annual charge on the benefits received from the water and the numerous deserted channels in various parts of the country show that unless carefully maintained these canals soon become useless.

Channels thus opening direct from the river and unprovided with regulating works are subject to several disadvantages. The current of a river may set on the mouth of the canal or on the bank and wash it away. The supply may become too great in the large floods or may be altogether cut off owing to the destruction of the head or the changing of the course of the river. The violent action on the mouth of the channel may be checked to a certain extent by revetments and groynes and other river-training works, but these also have the effect of diverting the action of the stream from its natural course and may throw it away from the canal head.

Nearly all Indian rivers from which inundation canals are diverted flow in broad curves through wide flood plains. At places where the curves have changed are extensive depressions containing water, called *dunds* in Sind and *sotas* in Bengal. These are similar in all

respects to the bayous or lagoons of the Lower Mississippi and neighboring rivers. These depressions are frequently the sites of the heads of inundation canals, though not infrequently such canals head in the true bank of the main river from which they draw their supply. The object in using dunds as canal heads is that they are much larger than the canals they feed, and as the velocity through them is correspondingly low, silt which would otherwise be deposited in the canal is deposited in the dunds, thus reducing the cost and difficulties of canal clearance.[a]

Experience seems to have taught the native rulers of India, who constructed most of the inundation canals, the necessity of locating head-works at points where they would be screened from the full force of the current during flood. Experiments by Colonel Tremenheere, R. E., on these show that: 1. Inundation canals which draw their sup-

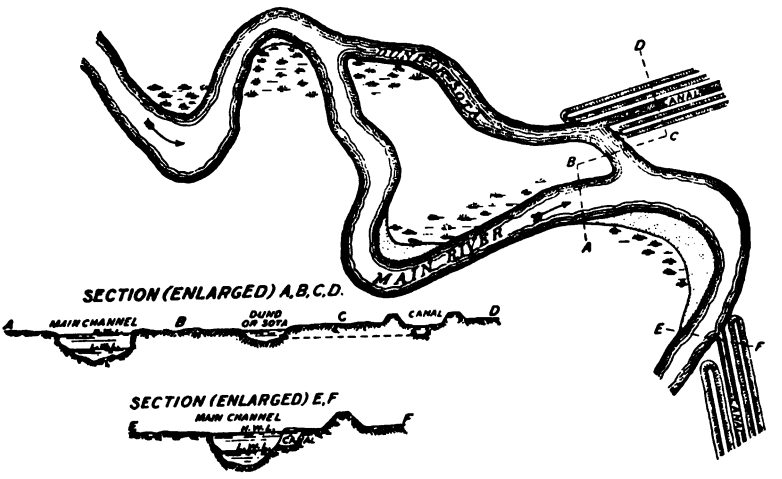


FIG. 5.—Inundation canal heading in dund.

ply from branches separated from the main river by islands covered by brushwood and long grass contain a comparatively small amount of suspended matter. 2. Canals having their heads in the main stream where the velocity is normal usually contain silt to the extent of one three-hundredths by weight, and that about one-third of this quantity may be deposited in the canals. 3. Canals having their heads in the main streams at a point where the channel is restricted and the velocity increased may contain silt to the extent of one two-hundredths by weight, of which one-half may be deposited in the canal.

In the Punjab the inundation canals begin to fill with water about the last of April and run dry toward the end of September. During the earlier months, when the flood is high, lift irrigation is practiced. The superiority of the river water for agricultural irrigation over

[a] Buckley, R. B., *Irrigation Works in India and Egypt*, E. & F. N. Spon, London, 1883, p. 18.

well water is demonstrated by the fact that near the heads of the Punjab canals the cultivators prefer to pay canal rates and to lift the water from the canals rather than from wells.

The freshets in the Indus commence in March and high flood is not frequent in August. The lower stages commence at the end of October. The velocity of the current in the dry season varies from 2½ to 3½ miles per hour. In the freshets it is from 5 to 7 miles per hour and has sometimes reached a maximum of 8 miles. The width of the water surface of the Indus in low water or the dry season varies from 1,500 to 3,000 feet, the average depth being from 3 to 6 feet. The rise of ordinary floods is from 5 to 7 feet in twenty-four hours and averages 50 feet above low-water level. The highest recorded flood was 92 feet above low-water level.

From the borders of the Punjab the Indus flows for a distance of 40 miles through an arid alluvial plain, almost every portion of which has at some time been swept by the river or its branches. Owing to the deposits of silt the bed and banks of the river are continually rising. It has been estimated that the Indus annually brings down sufficient silt to form an island 42 miles long by 27 miles broad and 40 feet deep. When the river bed attains a certain height the water falls over the bank and the river changes its course. It is this movement which causes the difficulties of irrigation in the Sind, and has resulted in the construction of inundation works.

Inundation canals are generally carried away from the river in an oblique direction. They vary from 20 to 300 feet in width and from 4 to 20 feet in depth, and resemble natural water courses more than canals. The following table gives an idea of the dimensions of six of the larger inundation canals in the Sind, and their cost and revenue for the year 1899–1900:

Sind inundation canals.

Name.	Main [illegible].	Discharge of canal.	Area irrigated.	Duty. acres irrigated per second-foot.	Average annual rainfall.	Capital outlay to 190[illegible].
	Miles.	*Second-feet.*	*Acres.*		*Inches.*	
Begari	158	5,664	186,500	55.62	0.79	$1,148,000
Desert		3,509	149,660	53.78	1.90	845,000
Ghar	298	3,210	250,000	39.24	.83	147,000
Sukkur	130	3,439	90,000	.....	.87	470,000
Fulelli	1,043	3,352	380,000	34.69	.80	563,000
Jamrao	101	3,200	250,000	.....	4.58	2,220,000
Total	.....	.....	1,306,160	.....	.....	5,393,000

[illegible] *Punjab* the capital outlay on the five inundation works for [illegible] capital accounts were kept was, to the end of 1901, $687,000.

me working expenses were $197,000 and the net revenue $74,000. me average per cent of net revenue on capital expended on these nals was 9.58, while on the Indus and Shahpur canals an interest 23.55 and 28.76 per cent, respectively, was realized.

The following table gives the important data concerning the six incipal inundation canals of the Punjab:

Punjab inundation canals.

Name.	Main canal.	Discharge of canal.	Area irrigated.	Average annual rainfall.	Capital outlay to 1901.
	Miles.	*Sec.-feet.*	*Acres.*	*Inches.*	
pper Sutlej	225	9,780	247,683	13.0	$276,000
wer Sutlej	363	5,700	271,545	6.8	.....
nnab	262	4,894	130,455	.....	.....
dus	713	5,164	225,000	6.6	238,000
ahum (Shahpur)	79	1,125	42,000	12.8	72,000
uzaffargarh	886	7,284	318,225	5.2	.....
Total			1,234,908		

The total area irrigated in the Punjab by inundation canals was 220,000 acres, about two-fifths of which were autumn crops.

DELTAIC CANALS.

Before entering into a discussion of the perennial canals of the igher lands of India a general description will be given of the great orks constructed near the mouths of the larger deltaic rivers, as many f the weirs and mechanical modes of controlling water in use on them ill be of interest. These canals have been constructed in an almost vel country, with low slopes, and are universally intended for avigation as well as for irrigation. Aside from the mechanical details eferred to, these canals are of little interest to the American engineer, s the conditions do not favor similar works in our country.

Deltaic canals are true perennial canals, but are here distinguished om the latter because they are situated on a different class of rivers om those found in the United States, and apart from the head-works, gulators, and other prominent works upon them do not resemble ich irrigation canals as are likely to be constructed in this country. s the name implies, deltaic canals usually head at the points at which vers divide into numerous branches as they enter their deltaic tracts ear the ocean, as does the Mississippi near New Orleans. A number f such canals have been built in India, of which several large ones re in Madras and two in Bengal.[a]

[a] Buckley, R. B., Irrigation Works in India and Egypt, E. & F. N. Spon, London, 1893, p. 23.

A river which runs through the soft soil of a delta easily changes its course, and the relative dimensions of the main channel and its bifurcations or branches are sometimes greatly altered by floods. An example of the extent of such changes may be cited in the case of the floods on the Mahanadi River, which were carefully measured. It was calculated that during the period which elapsed between the floods of 1855 and 1872 the capacity of the Mahanadi branch had diminished to the extent of nearly 80,000 cubic feet, or 10 per cent of its ordinary volume. A common feature of deltaic rivers is observed in the diminution of the areas of their cross sections as they approach the sea. This is shown in the discharge at the head of any particular reach of the river being always greater than the noted discharges at the heads of the branches which take off at the lower end of such reach.

There are many advantages in irrigating upon a river delta, as the soil there is usually a rich alluvium and the slope of the country always uniform and gentle. Moreover, the branches of the stream flowing through the land are of uniform slope, and thus afford excellent drains for the surplus water. As the river channels flow in built-up ridges somewhat above the level of the surrounding country, it is possible by throwing a weir across the delta head and running branch canals along the margins of the streams to easily command the whole delta area for irrigation. As from the nature of the conditions the whole area under command of the canals is subject to inundation, it is necessary to confine the floods to the river channels by means of a series of marginal embankments or levees. As such rivers have a tendency to change the amount of flood which they pass through different branches, it is generally necessary to regulate the discharge of each of these by weirs across both the main and branch channels. Furthermore, because the cross sections of the branches reduce as they approach the sea it is essential in designing levees that provision be made to permit the discharge of the full volume which any branch may have to carry.

An admirable example of deltaic canal is furnished in Egypt in the delta of the Nile, between Cairo and Alexandria. A few miles below the former city, at the head of the delta, is a great masonry weir, the Barrage du Nil. This consists essentially of two great open regulating bridges placed across the two deltaic branches of the Nile, the Damietta and Rosetta branches. The floors of these regulators are at the level of the river bed, and the only obstruction offered to floods are the piers. The openings between the piers are 16.4 feet in the clear, covered with arches, which carry the roadway overhead. There are 71 spans in the Damietta barrage and 61 in the Rosetta barrage. The entire length of the former is 1,765 feet and of the latter 1,525 feet, and these afford an obstruction to the Nile amounting to about one-fourth of the original waterway.

In the presidency of Madras the most notable canals of this char-
ıcter are those at the deltas of the Godavari and Kistna rivers. On
he Godavari system there were completed, at the end of 1899, 503 miles
of main canals and 1,905 miles of distributaries, which commanded
1,267,200 acres and actually irrigated 653,400 acres. The total expendi-
ture on this work to end of 1899 was $4,355,000. The weir at the head
f this canal was constructed in 1844. The river drains an area of
15,570 square miles above the weir, and the crest of this latter is 38
eet above mean sea level and 33 miles from the coast. The maximum
ischarge of the river at this delta head was 1,210,000 second-feet, with
depth of 15½ feet over the weir crest. The head-works at Doulesh-
aram consist of a weir across the river 18,000 feet in length and of
ıree sets of scouring sluices and regulators from which the three
ain canals irrigating the eastern, central, and western deltaic regions
e supplied. The river is broken by islands to a length of 4,500 feet,
ı which earth embankments connect the various portions of the
asonry weir. There are also flanking embankments, making the
rthwork in all 7,000 feet long, and there are 2,500 feet in length of
ing walls. The total length of the masonry weir is 11,946 feet. It
founded on walls 6 feet in diameter sunk 6 feet in the river bed,
ıd is 19 feet thick, consisting of a core of sandstone faced by a
rtain wall 7 feet high and 4 feet thick at the base, having a masonry
ll 28 feet broad and 4 feet thick. Below the weir is a massive stone
ron 80 feet broad. On both banks are masonry wing walls and
vetments. The three sets of regulating sluices have the following
mensions: The eastern consists of 13 gates 6 by 8 feet, the central
15 gates 6 by 8½ feet, and the western of 15 gates 7½ feet high and
rying from 5½ to 6 feet in width. The mean supply to the eastern
lta during the summer season is 2,826 second-feet, which is the
rrying capacity of that canal. The area irrigated is 170,000 acres.
he maximum discharge of all the main canals during 1899 was 13,201
cond-feet. The carrying capacity of the main central canal is 1,745
cond-feet, and it irrigates 122,400 acres. The supply of the western
nal is 3,950 second-feet and it covers 319,580 acres. The canals vary
bottom width from 114 feet on the central canal to 225 feet on the
estern canal, with varying depths of from 7 feet on one to 10 feet
the other.

The River Kistna has a course of about 800 miles from its source in
itude 18° 01′ and longitude 73° 14′, down to the sea, about 45 miles
uth of Masulipatan on the Coromandel coast. Its drainage area
ay be taken at 97,050 square miles, and its maximum flood discharge
820,000 feet per second (fig. 6).

The idea of damming this river by an anicut at Bezwada, 60 miles
ove its mouth, where the configuration of the country lent itself in
exceptional manner to the construction of such a work, was first
oted in the year 1792, but nothing was definitely decided until 1847,

when Maj. (now Sir) Arthur Cotton and Capt. (now Sir) Atwell Lake submitted a joint report on the proposed anicut and on the scheme of irrigation for the eastern and western deltas. After considerable discussion the court of directors sanctioned the construction of the anicut, together with subsidiary works, on the 5th of January, 1850, for a sum of $513,000. The head sluices and locks were commenced in 1852 and completed in the following year. The anicut itself was commenced in November, 1853, and completed in 1855, in spite of great delays and losses caused by an extraordinary flood and an outbreak of cholera.

The head-works consist of a weir 3,198 feet in length, and the greatest flood rose 19½ feet above its crest. The eastern main canal has a

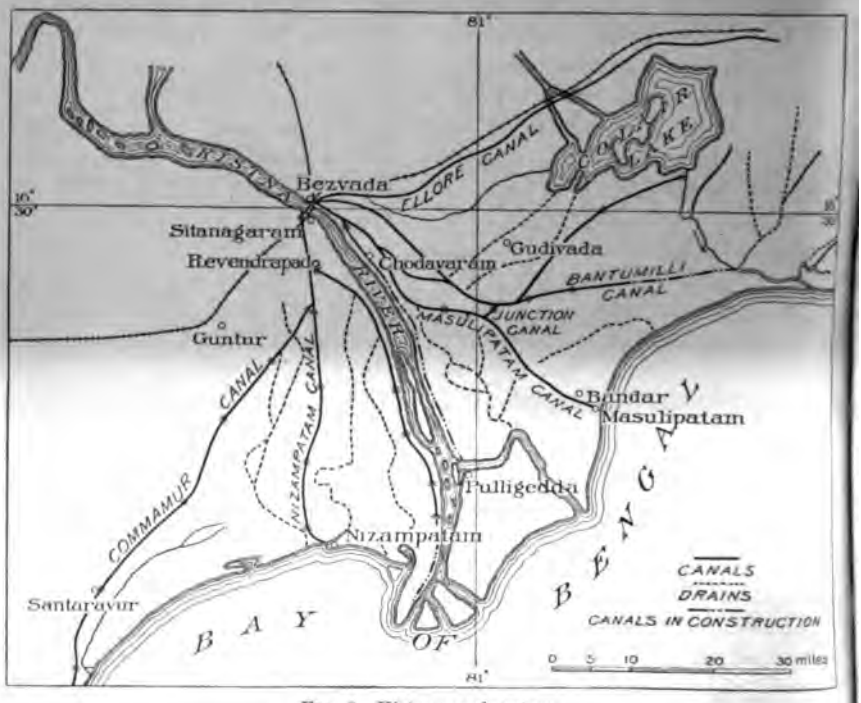
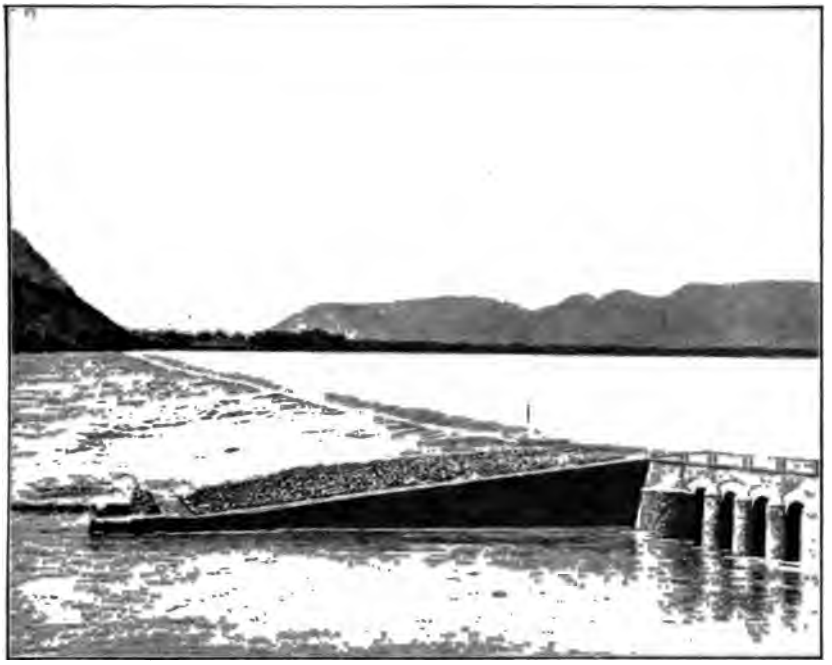


FIG. 6.—Kistna canal system.

bottom width of 200 feet and a depth of 8¼ feet. The western canal has a bottom width of 230 feet and a depth of 8 feet. The total length of main canals in 1899 was 372 miles and of distributaries 1,625 miles. The total area of irrigation in 1899 was 505,087 acres. The crest of the weir at the head-works is 6 feet in width and 15½ feet above the top of the foundation. The total width of apron below the crest is 257 feet. (Pl. V, *A*.) The foundation consists of a double row of wells, and at each end of the weir is a set of scouring sluices of 30 gates, each 6 feet wide. The regulating gates are of the same dimensions. The crest of the weir being too low for the required supply, a temporary dry stone wall 4 feet high is annually built on it, and after the stone has



A. KISTNA ANICUT, WITH RIVER IN MODERATE FLOOD.

B. HEAD SLUICES OF EASTERN CHANNEL FROM KANIGIRI RESERVOIR.

washed off by floods it is used in the repair of the apron. Shut-
ıave recently been substituted for this temporary device.

e Cauvery deltaic canals, from the river of that name in Madras,
ıted 919,540 acres in 1899. The length of main canals is 844
, of distributaries 1,250 miles, their maximum discharge being
0 second-feet. So far the cost of these works has been $704,000.
e data upon which the size of the head sluices and main canals
calculated was 2 cubic yards of water per hour per acre, or a
of 66 acres per cubic foot per second. This, it was calculated,
l be maintained for the ultimate proposed area of irrigation of
00 acres throughout the irrigation season except for about forty
in the year. Experience, however, has proved that, owing to
ıeavy clayey nature of the delta soil and care taken in the distri-
ɔn of the water and its utilization by the ryots, that a duty of 90
; per cubic foot per second may be reckoned upon, pointing to
ltimate development of no less than 700,000 acres, or 50 per cent
cess of the originally calculated irrigable area.

e East Tamileru escape or Chattaparru outlet at 40 miles 20
ıs, Ellore Canal, eastern delta, was built in 1890–91 to provide
assing the flood water of the east branch of the Tamileru out of
canal. The work consists of four arches, 20 feet span each, at
r end, and eleven small arches between 7½ feet span each, the
r fitted with screw-gearing shutters. There is a footbridge over
ntire work.

Sangam anicut project was sanctioned in 1881 for the purpose of improving
xtending irrigation in the northern section of the Penner River delta. Its
pal features were the construction of a weir 4,290 feet long; a head sluice of
ıts, of 4½ feet span each, to supply the main canal; the excavation of a main
6 miles long and 157 feet bottom width, to fill the Kanigiri reservoir;
vements to an existing branch channel, which was to be supplied from the
canal; raising the banks of the Kanigiri reservoir, to increase its capacity,
ıe excavation of distributaries from the Kanigiri reservoir and Duvur tank.
ınticipated ultimate area of irrigation under the project was 94,000 acres
cing a net revenue of $78,900.

works have been carried out more or less as they were designed. The pro-
ame into operation in 1886–87, and there has been a steady increase of cultiva-
except in 1891–92, when there was a falling off, owing to the scarcity of water,
ı amounted nearly to famine in the Nellore district. According to the
ıs of 1895–96 the area irrigated was 77,347 acres and the net revenue, after
ting working expenses, amounted to $44,000.

gam anicut is built across the Penner River at the village of Sangam and
ıts of a solid wall of masonry with scouring and head sluices, all founded on
The rear of the anicut is provided with a substantial sloping apron built
ge bowlders with the interstices filled in with concrete and strengthened
ıding walls.

length of the anicut crest between south wing and scouring sluice is 4,076
top breadth, 4½ feet. The upper course is built to a thickness of 2 feet, with
terite set on edge in Portland cement. The crest is 7 feet above deep bed of
or 10.50 feet above M. S. L. The anicut has been designed to discharge

597,000 cubic feet per second and the wings and other masonry works attached to it have been built to meet the contingency of an additional 5 feet rise of water in the river during extraordinary floods. The scouring sluice, which is built in continuation of the anicut, is constructed of brick in surki mortar, except the floor and apron, which are paved with cut stone, and the sides and faces of piers cased with cut laterite. It is provided with 14 vents, 6 by 6 feet, which are opened and closed by means of screw-gearing shutters. The under sluice is also intended to pass down the regulated share for the Nellore anicut system lower down the river.

The Sangam head sluice is built in similar style to that of the scouring sluice and has 21 vents, 6 by 6 feet, for the regulation of water into the Kanigiri main canal, which supplies the Kanigiri reservoir. It has been designed to supply water for the irrigation of 94,000 acres by a discharge of 4,800 cubic feet per second when water in river is flush with anicut crest. The floor level of the sluice is 98′ M. S. L., or 2 feet above that of the under sluice.

Kanigiri tank head sluice, southern channel, is intended to discharge sufficient water for the irrigation of 17,500 acres under southern channel and 10,500 acres under branch or central channel. It is built of brick in surki mortar, the floor and apron being paved with cut stone. It is provided with 4 vents, 6 by 4 feet, and worked with screw-gearing shutters. Eastern channel head sluice is built of brick in mortar with the exception of the floor, which is paved with cut stone, and the piers cased with cut laterite. [Pl. V, *B*.] It has 16 vents, 6 by 4 feet, capable of discharging 934.5 cubic feet per second when the reservoir maintains F. S. L., the area to be irrigated under the channel and its branches being 62,300 acres. The supply of water to the channel is regulated by means of screw shutters. The sill level is 73′.

Kanigiri masonry dam or flush escape [Pl. VI] is intended to pass the surplus of the reservoir over rocky ground, and is built entirely with rubble in surki mortar, the crest being placed 2 feet below F. S. L. (94′.95) of the reservoir, or 92′.55 M. S. L.; but in order to maintain a full supply, grooved iron standards have been fixed on top, provided with planks for raising and lowering the water as required. The length of the dam is 280 feet, with a top breadth of 4½ feet.

Kanigiri escape sill is placed on the same level as the crest of the masonry dam and acts jointly with it. The masonry is composed of brick in surki mortar, resting on rock foundation. The escape consists of 31 arches of 9 feet span with a roadway on top, and in front screw-gearing shutters have been fixed to hold up the water to F. S. L.[a]

The principal remaining deltaic canals in India are the Midnapore and Orissa canals in Bengal. According to the revenue report of Bengal for the year 1901, it appears that the total capital outlay to date on the Orissa canals, exclusive of interest charges, was $17,436,000, and on the Midnapore canals, $5,953,000. The Orissa canals were originally constructed by the East India Irrigation and Canal Company and the source of supply is derived from three principal rivers—the Mahanadi, the Brahmini, and the Byturni. The minimum discharge of all these rivers during the cold weather or autumn crop is 6,612 second-feet, and the maximum discharge of the canal is 6,058 second-feet. The gross area commanded is 597,792 acres, of which at present 274,974 are irrigated. The works consist of 280 miles of main and branch canals and 1,123 miles of distributaries. There are three distinct weirs at the head of this canal. One at the point where the

[a] Administrative report Irrigation Branch: Public Works Dept., Madras Presidency.

KANIGIRI RESERVOIR ESCAPE

er bifurcates is 3,600 feet in length and 12 feet above the river bed. e second weir is across the Mahanadi River itself, and is 1¼ miles ıg and 12 feet high. The third, across the Biropa River, is 1,980 et in length and 9 feet above the river. The system of canals is pable of great extension.

The Midnapore canal was also constructed by the East India Irrition Company. Its supply is derived from the River Cossye, the tchment basin of which is so small that the supply of water in the nal varies with the rainfall on the district covered by the canal elf. The works were commenced by a company in ignorance of the al supply available, and the distributaries have actually been conructed to command an area of 180,000 acres, of which 125,000 are at esent irrigable.

The canal is divided into four lengths, the first of which is taken off ove the weir at Midnapore. In the twenty-fifth mile this tails into e river where the second weir is built across it. The canal crosses e river at this point and the second length is diverted on the oppote bank. A large portion of the remaining length of the canal is nstructed principally for navigation. The automatic sluice gates nstructed in the weir at Midnapore are of peculiar interest and will fully described in another place.

Deltaic canals.

Name of canal.	Province.	Main canals.		Area irrigated.	Rainfall.	Expenditure to 1901.
		Miles.	*Discharge, sec.-ft.*	*Acres.*	*Inches.*	
sa	Bengal	280	6,058	274,974	75.8	$17,436,000
napore	do	72	1,500	125,000	59.6	5,953,000
lavari	Madras	503	13,478	662,210	42.8	4,355,000
tna	do	372	8,942	547,806	27.4	4,465,000
ner	do	31	6,634	145,470	30.1	1,987,000
ar	do	163	5,546	45,206	25.2	697,000
nool	do	190	1,440	62,008	25.2	7,275,000
very	do	844	45,525	919,539	52.3	919,000

CHAPTER VII.

PERENNIAL CANALS.

SOURCE OF SUPPLY.

Perhaps the first consideration in designing any irrigation work is the source of supply. In the case of perennial canals this may be from perennial streams or from storage reservoirs. In either case the Indian engineer deems it necessary first to make a thorough examination of the hydrography of this source to ascertain the quantity of water available and the point of the river's course at which the canal can be taken off. The head-works are almost invariably located high up on the river to command a sufficient level and if possible to tap the stream where the water is clear and not laden with silt. By thus locating the head-works it is usually possible, owing to the greater slope of the country, to reach the high lands or watersheds of the areas to be irrigated with the shortest possible diversion line. By diversion line is meant that portion of the canal's course which is necessary to bring the line to the neighborhood of the irrigable lands, and which is usually unprofitable, as it does not irrigate directly any land. The disadvantages of locating the canal head-works high up on the streams are serious. The country having an excessive fall requires rough hillside cuttings, perhaps in rock, and the line is, moreover, intersected by hillside drainage, the passage of which entails serious difficulties.

Perennial canals are taken chiefly from the great perennial rivers which issue from the Himalayas, from whose melting snows the canals receive an abundant and constant supply of water. The smaller perennial canals in portions of Madras and Bombay are chiefly fed by storage water collected in reservoirs and tanks in the hills. The great rivers of the Punjab and the Northwest Provinces rarely discharge less than 4,000 second-feet, and some discharge many times this volume, while in times of flood their discharge increases to as high as 1,200,000 second-feet and more.

In the arid region of the United States no such streams as these exist, though a few of our great rivers, as the Missouri, Columbia, Rio Grande, Sacramento, and their principal branches, carry large volumes of water, much of which it is to be hoped will at some future time be utilized for irrigation. Because of the similarity existing between these and the great Indian rivers, the country which they traverse, and its climate during the cultivation of the autumn crop

use of the waters of these great streams will be of immediate interest to us and may furnish useful lessons and examples when we commence the construction of similar works. The topography of the Punjab and Northwest Provinces at the foot of the Himalayas has been described in detail in another place. It is very similar in many respects to that of the great California Valley on the western slopes of the Sierras and that of the Colorado and Wyoming plains at the foot of the Rockies. The rivers issue from the sub-Himalayas and Sewaliks through foothills similar in appearance and with surface slopes corresponding to those of the Feather, American, Stanislaus, and other rivers flowing from the Sierras in California, or to the Arkansas and Platte rivers issuing from the Rockies.

In designing these great perennial canals the Indian engineer first makes a careful topographic survey of the entire region to be irrigated, and numerous trial lines are run before the final location of the main and distributary canals is decided upon and the position of the head-works definitely fixed. In the case of the rivers having a constant regimen training works are unnecessary, as the head-works are generally located in narrow portions of the river where the banks are firm and the channel stable. At the entrance to some of the larger canals heading in the plains, notably the Agra and the Lower Ganges, expensive river-regulating works are required to control the movements of the river channels.

The machinery of a great canal consists usually of the following parts: The head-works at the point where the canal is diverted from the river, the main canal, the distributaries, and the minors. Each of these units of the system has its own set of regulating works and escapes to control the supply of water in the canal. Between different canals these differ but slightly, the point of greatest difference usually being at the head-works and in the first few miles of diversion line. Here various devices have been resorted to for the passage of hillside drainage.

GANGES CANAL, NORTHWEST PROVINCES.

It is probable that the first attempt to construct a canal on the interfluve between the Ganges and Jumna rivers occupied by the present line of the Ganges canal was made by Mohammed Aboo Khan at some time early in the eighteenth century. This canal consisted of a shallow ditch 12½ miles long taken from the west Kali Nadi and was filled by means of a temporary weir thrown across that stream. No masonry works were constructed, and much damage was done by the flooding of lands above the weir. The second attempt here made was in 1827, when Captain Debude tried to restore the above by putting in permanent head-works across the Kali Nadi. This plan contemplated the extension of the canal through Meerut to Aligarh, and it was also intended that a dam should be thrown across the Hindun River and

the water of both streams utilized. This was merely an attempt to improve on old and bad methods. The third and present project was purely a British one. In 1836 Col. John Colvin, C. B., proposed to build a canal from the Ganges River heading at Hardwar.

The famine of 1837 and 1838 caused an increased desire for the construction of this canal, and in 1839 Lord Auckland, the Governor-General, sanctioned the surveys. In 1840 Sir P. T. Cautley made the first surveys and reported on the project, and from then to 1845 about $50,000 per annum was expended chiefly on surveys. In his report[a] Colonel Cautley said:

> To deny the value of irrigation to agriculture in an arid country is like denying the value of manure to an European farmer.

On the strength of the report made in 1840 the board of directors decided on the construction of the Ganges canal as an irrigation work, the canal as sanctioned being designed to carry 6,750 second-feet. When Lord Ellenborough was Governor-General, between 1842 and 1843, he did everything to discourage the project and so modified the sanction that only a small navigation canal could be constructed. During Lord Ellenborough's governorship to 1847 Colonel Cautley was in England attempting to further the project, and the works were carried on by Major Baker. In 1848 Lord Harbinge became Governor-General, and sanctioned the work as originally devised, urging its immediate construction, which was at once prosecuted by Colonel Cautley.

In 1845 Colonel Cautley submitted detailed estimates for three separate projects, in each of which the discharge at full supply was to be 6,750 second-feet, of which it was assumed that 1,000 second-feet would be lost by evaporation, absorption, and navigation. The last of these projects was estimated to cost about $4,670,000 and render irrigable an area of 1,470,000 acres. When in 1847 the Government directed that these works should be constructed, among other instructions they said that the primary object of the canal was to be irrigation, navigation being carried only as far as not inconsistent with irrigation, thus reversing the instructions of Lord Ellenborough's government.

Water was first admitted into the canal in 1854 and irrigation commenced the following year. During the next few years defects in the works gradually came to light, and in 1864 an investigation was ordered by the government. At the close of that year detailed estimates were submitted for rectifying the principal of these defects. Previous to this Sir Arthur Cotton reported on the works considered by him necessary for the improvement of the canal. In his report he stated that the head of the canal was too high up on the river; that the whole canal had been so cut as to carry the water below the level of the surface, entailing a vast unnecessary excavation; that the whole

[a] The Ganges Canal, 3 vols., London, 1860.

GOPALPUR BIFURCATION, GANGES CANAL.

feet in width separates from the main river and, hugging the Hardwar shore, rejoins the stream a half mile below Hardwar. The discharge of the main river at this point in the dry season is about 8,000 second-feet, the greater part of which is diverted by training works and temporary bowlder dams into the Hardwar channel. This has been deepened and given a uniform slope of 8½ feet per mile to the canal head. At Myapur the canal is taken from the Hardwar channel, the water being diverted into it by means of a weir and sluices across the channel and a masonry regulator at the head of the canal. To the sixth mile the canal crosses several minor drainages which are admitted by means of little inlets. At the sixth mile it is crossed by the Ranipur Torrent, passed over it by means of a masonry superpassage about 195 feet in breadth. In the tenth mile the Puthri Torrent having a catchment basin of about 80 square miles, or twice that of the Ranipur, is carried across the canal by a similar superpassage 296 feet in breadth. The sudden flood discharges in these torrents are of great violence, the Puthri Torrent discharging as much as 15,000 second-feet and having a velocity of about 15 feet per second.

In the thirteenth mile the canal encounters the Rutmoo Torrent, with a slope of 8 feet per mile and a catchment basin half as large again as that of the Puthri. This torrent is admitted into the canal at its own level. In the side of the canal opposite to the inlet is an open masonry outlet dam or set of escape sluices. In the canal just below this level crossing is a regulating bridge by which the discharge of the canal can be readily controlled. Thus in time of flood, by opening the sluices in the outlet dam and adjusting those in the regulator so as to admit into the canal the volume of water required, the remainder is discharged through the scouring sluices, whence it continues in its course down the Rutmoo Torrent.

In the nineteenth mile, near Roorkee, the canal crosses the Solani River and Valley on an enormous masonry aqueduct. The Solani River in times of highest flood has a discharge of 35,000 second-feet, and the fall of its bed is about 5 feet per mile. The total length of the aqueduct is 920 feet. The banks of the canal on the upstream side are revetted by means of masonry steps for a distance of 10,713 feet and on the downstream side for a distance of 2,722 feet. For 1¾ miles above the aqueduct and for a distance of half a mile below it the bed of the canal is raised on a high embankment. The greatest height of the canal bed above the country is 24 feet. The aqueduct proper consists of fifteen arches of 50 feet span each. In addition to these great works there are in the first 20 miles of the canal five masonry works for damming minor streams and a number of masonry falls.

Beyond Roorkee the main canal follows the high divide between the Ganges and the West Kali Nadi, and continues in general to follow the divide between the Ganges and the Jumna to Gopalpur, a short distance below Aligarh, where the main canal bifurcates (Pl. VII).

GOPALPUR BIFURCATION, GANGES CANAL.

orming the Cawnpur and Etawah branches. The former branch tails into the Ganges at Cawnpur and is 170 miles in length. The Etawah branch is also 170 miles long and tails into the River Jumna near Humerpur. The Vanupshahr branch leaves the main line at the fifteenth mile and flows past the towns of Vanupshahr and Shahjahanpur. It formerly terminated at mile 82½, emptying into the Ganges River, but it is now continued to a point near Kesganj, where it tails into the Lower Ganges canal. The first main distributaries are taken from both sides of the canal a short distance below Roorkee. The nature of the country offers abundant facilities for escapes from the canals. Five are constructed on the main line, four on the Cawnpur branch, and three on the Etawah branch, besides numerous small escapes to the distributaries. These escapes will be described in another place. They are essential for the proper regulation of the canal in the discharge of local drainage.

The maximum discharge of the canal is 7,782 second-feet. The average annual rainfall over the area irrigated is 31.9 inches. The entire area commanded is 2,800,000 acres. The culturable area is 1,820,000 acres, and the area irrigated is 1,600,000 acres. The maximum area irrigated within any one year, including both spring and autumn irrigation, was 2,800,000 acres in 1883; the total length of main canals is 419 miles. There are 2,552 miles of distributaries and 859 miles of drainage cuts and escapes, or a total of 3,830 miles.

Of the total area irrigated in 1893, 96,543 acres, or 13.4 per cent of the whole, were double cropped and the duty performed by the canal for the autumn crop was 135 acres per second-foot on the discharge at the head, or 155 acres per second-foot on the discharge utilized. The total capital outlay on these works to the end of the year 1893 was $10,127,000, and the working expenses for that year were $375,000. The working expenses per second-foot of discharge at the head were $103, or 52 cents per acre irrigated. The total water rate derived was $1.30 per acre irrigated, or $253 per second-foot of discharge at the head. Among the principal crops culivated in 1888 were 106,000 acres of sugar cane, valued at $2,332,000; 228,300 acres of wheat, valued at $3,275,000; 31,400 acres of rice; 80,000 acres of indigo, and a grand total, including all other crops, of 601,900 acres, valued at $7,600,000. The net profits in 1888 were 5.4 per cent on the capital invested.

The number of days in the year when water was supplied for irrigation and the canal was in active operation was, in 1888, 275. In this year a comparatively small supply of water was used, the mean supply being only 2,400 second-feet.

LOWER GANGES CANAL, NORTHWEST PROVINCES.

As described in relating the history of the Ganges canal, the Lower Ganges canal was undertaken at the suggestion of Sir Arthur Cotton, in 1868, after an investigation by Col. R. Strachey in 1865, as a means of relief or improvement of the Ganges canal. It irrigates a part of

the Ganges-Jumna interfluve that was originally intended should be commanded by the Ganges canal proper. The work comprises a masonry diversion weir at Narora, about 3 miles below the railway crossing at Rajghat. It relieves the Ganges canal of 128 miles of the Cawnpur branch and 130 miles of the Etawah branch, and as originally projected was intended to carry 6,500 second-feet in the spring season and 3,270 second-feet in the autumn season. In 1871 the works were commenced, but were delayed awaiting a revised estimate submitted in 1876, when the work was finally commenced. It is now considered as a work separate from the Ganges canal.

The weir is a substantial one, resting on masonry wells, usually 20 feet deep; the front and rear curtain walls rest on smaller wells. The weir is 3,800 feet long and is 10 by 10 feet in cross section, having a vertical overfall to a paved floor. It is constructed chiefly of brick. There are 42 weir scouring sluices opposite the canal head, each 7¼ feet wide. The regulator at the canal head is constructed of masonry and has 30 openings each 7 feet wide. The weir crest is 7½ feet above the sill of the canal and this can be raised to 10 feet by means of shutters. For the first 26 miles of main canal the bed is 216 feet wide; the full supply depth is 10 feet and the slope one-tenth of a foot in 1,000.

In the first portion of its line the canal is compelled to follow the low river bottom for some distance before its grade enables it to surmount the banks and reach the summit of the interfluve. In this low reach the canal is threatened constantly by the encroachments of the river and extensive river-training works are necessary to preserve its integrity. These extend for a distance of 4 miles above the canal head and 15 miles below, and consist chiefly of long earthen groins or embankments, sometimes 2½ miles in length, projecting into the stream at right angles to its course and protected at the end by loose rock noses. The general slope of the Ganges River and of the country at this point is about 1½ feet per mile and the greatest flood the river has discharged is 350,000 second-feet. Its minimum discharge has been as low as 1,200 second-feet. The velocity in the canal is very low, being but 2 feet per second, and as a result much silt is deposited and the growth of weeds is excessive. The maximum discharge of the canal as now constructed is 5,100 feet. The average annual rainfall on irrigable land is 34.5 inches; the gross area commanded is 4,387,200 acres, and the culturable area 2,435,400 acres, and 1,187,326 acres will be irrigated when the project is completed, though at present but 833,951 acres are irrigable. The total length of the main canals is 557 miles. There are 2,159 miles of distributaries and the total length, including escapes and drainage cuts, amounts to 3,123 miles.

The capital outlay to the end of 1893 was $12,073,000. The total receipts in that year amounted to $114,000, a little less than 1 per cent net profit on the capital invested. The area irrigated in 1888 during the autumn crop was 327,000 acres, of which 184,000 acres were irri-

ted by wells. Twenty-three per cent of the whole was double-opped, and in the autumn season 1,765 second-feet of water were ilized, the duty on which was 185 acres per second-foot. The cost of aintenance of the distributaries was $13 per mile. There were 222 ores irrigated per mile of distributaries at a cost of a little less than a hundred acres, and the average depth of water used in these was 1 feet. The most notable works on this canal will be described in eir proper place. They are the training works, the weir and other ead works, and the great aqueduct at Nadrai, by which the canal is arried over the Kali Nadi Torrent.

AGRA CANAL, NORTHWEST PROVINCES.

The Agra was the third of the great perennial canals of the Northvest Provinces visited by me. This canal was contemplated when he question of the remodeling of the Ganges canal was being agiated in 1864. It was then pointed out that water might be drawn from the River Jumna below Delhi to supplement the irrigation of the Ganges-Jumna bench lands. The idea was further discussed in 1866. In 1867 projects were submitted and in 1868 the works were sanctioned for the purpose of famine relief. The works as eventually sanctioned in 1872 correspond closely to the present completed Agra canal project. It was formally opened in March, 1874. In 1875 it was found that the original weir was insufficient. The great flood of that year had seriously injured the scouring sluices and the works were then reconstructed. The head works of the canal are situated at Okhla on the River Jumna, 10 miles below Delhi, and consist of a weir about 2,573 feet in length at a point where the river is 4,400 feet wide. The left wing of the weir rests on an island, whence it is continued as an earth embankment 20 feet wide on top. This weir rests on wells sunk in the deep sands of the river bed. On the upstream side it has a slope of about 1 in 4, the downstream slope being very long, as flat perhaps as 1 in 20. As originally constructed in 1870, this weir was not more than 130 feet in width from toe to heel, but after being injured by successive floods it was carried out and added to until its width is now over 240 feet. The scouring sluices are 139 feet long at the end of the weir, and are composed of 16 gateways of 16 feet each. The regulating sluices consist of 12 openings, each 6 feet wide and 10 feet high, to the springing of the arches, and are so located as to avoid the deposit of silt at the canal head. The water of the river is deflected toward the right bank against the regulators by a series of groynes and river-training works. There are about 8 miles of embankment along the river margin to protect the low land from inundation and to prevent the flank wall of the weir from being turned.

From Okhla the canal follows the high land between the Khari Nadi and the Jumna, and its course throughout is fairly parallel to that of the Jumna, about 3 to 12 miles from its right bank. It finally tails

into the Ootunghun River about 20 miles below Agra. The main branches connect the canal with Muttra and Agra.

The source of supply is from the Jumna River. The highest recorded flood was of long duration and rose 50 feet above low-water level, the velocity then being 12 feet per second and the discharge about 1,300,000 second-feet. The supply of the Jumna having fallen occasionally below 800 second-feet it is supplemented by a cut from the Hindun River, which discharges into the Jumna just above the diversion weir, and is capable of supplying 300 additional second-feet. The grade of the canal from the head to the thirty-second mile is 6 inches per mile. There is a fall of 5.75 feet, beyond which the gradient is increased to 1 foot per mile to the end. In the first portion of the canal the bed width is 70 feet per mile and the depth from 6 to 10 feet, while the velocity is from 2 to 2½ feet per second. Below the first fall the bed width is decreased to 60 feet and the maximum depth to 7 feet. Beyond the one-hundredth mile the velocity is from 1½ to 2½ feet per second, the bed width 20 feet, depth 5 feet, and the discharge about 200 second-feet.

The Hindun cut is 9 miles in length and 24 feet wide at the bottom, with a mean depth of 5½ feet. The works of especial interest on this canal beyond those of the weir and head-works proper are an interesting superpassage made of boiler iron situated at about the eighth mile, and some drainage settling basins constructed as reservoirs for the collection and concentration of numerous small drainage channels. The total length of main canal as completed is 134 miles and there are 558 miles of distributaries. Its total maximum discharge is 1,500 second-feet. The average rainfall on its irrigated lands is 27 inches; the gross area commanded 768,000 acres, nearly all of which is culturable, while the area irrigated is 240,000 acres. The total capital outlay to the end of 1888 was $3,010,000, and the net revenue varies between 3 and 4½ per cent per annum.

Of the total area irrigated in 1888, 11 per cent was by means of wells. The water rate charged was $233 per second-foot of water utilized, or $1,120 per mile of canal; the cost of maintenance was $11.50 per mile, and 74 acres were irrigated per linear mile at a cost of $5.15 per 100 acres. The average depth of water used in the autumn season was 1.2 feet. The principal crops cultivated were much the same as those cited for the Ganges canal, the cultivation of indigo heading the list with an acreage of 28,500 acres, cotton being second with 22,000 acres, and pease next. The area of wheat cultivated was 14,500 acres, and the total value of all crops $1,090,000.

The canals of the Duns are usually small and have been constructed in a mountainous country at a rate of expenditure that would be considered quite unwarranted and prohibitive in the United States. There are five principal canals in the Duns, ranging from 11 to 19 miles in length and aggregating 67 miles. They have annually returned

over 6 per cent interest. These canals command 5,000 acres, more or less, each. The works are simple in character, but owing to the great rainfall expensive masonry aqueducts crossing high valleys and broad torrents are numerous, and in many cases the canal channels are constructed wholly of masonry for long distances. The total maximum discharge of these canals is 240 second-feet, and the precipitation on the irrigated lands averages 100 inches. They irrigate a gross area of 25,000 acres. The capital outlay on their construction was $1,070,000, and while the average interest received is over 6½ per cent, on some of them it exceeds 12 per cent. The crops cultivated are similar to those produced elsewhere in the Northwest Provinces, but wheat and rice far exceed in amount all other crops together. In 1888 there were 15,400 acres of food crops grown, nearly four-fifths of which consisted of wheat and rice.

SIRHIND CANAL, PUNJAB.

Of the important perennial canals in the Punjab, the Sirhind far exceeds all others in matters of engineering interest, as it is the most recent and modern in construction, besides being one of the greatest. Of the other important canals of the Punjab, the principal are the Bari Doab and the Western Jumna, two of the most profitable canals in northern India. The Sidhnai canal, which has only recently been opened, was, as originally constructed, an inundation canal and is still partially operated as such. Though I saw little of the Sirhind or Sidhnai canals, a brief description of each will be given, as they represent some of the latest developments of irrigation as practiced in India.

In the time of the Emperor Feroze attempts were made to utilize the waters of the Sutlej River for irrigation. These attempts were, however, of little moment. Maj. W. E. Baker first showed the practicability of a canal from the Sutlej to irrigate what was known as the "Hard Desert" in the districts of Hissar and Bhuttiana. The few wells there were so deep that irrigation from them was impossible, while the water was impure and brackish. The population was scanty and lawless, their chief occupation being cattle raising. The question was not how to improve agriculture, but how to create it.

Major Baker proposed heading the canal above Rupar, utilizing the line of the old canal of Mohammed Shah, but Col. Baird Smith, who examined this project, reported that "the occupation and repair of old canals was the most fruitful source of evil in the existence of canals," and he suggested a new alignment.[a] Major Baker's investigations were carried out in 1840, and the project then submitted was very similar to that of the now completed Sirhind canal. In 1860, at the request of the Maharajah of Pattiala, who offered to defray the expenses, the whole question was investigated by the British officers.

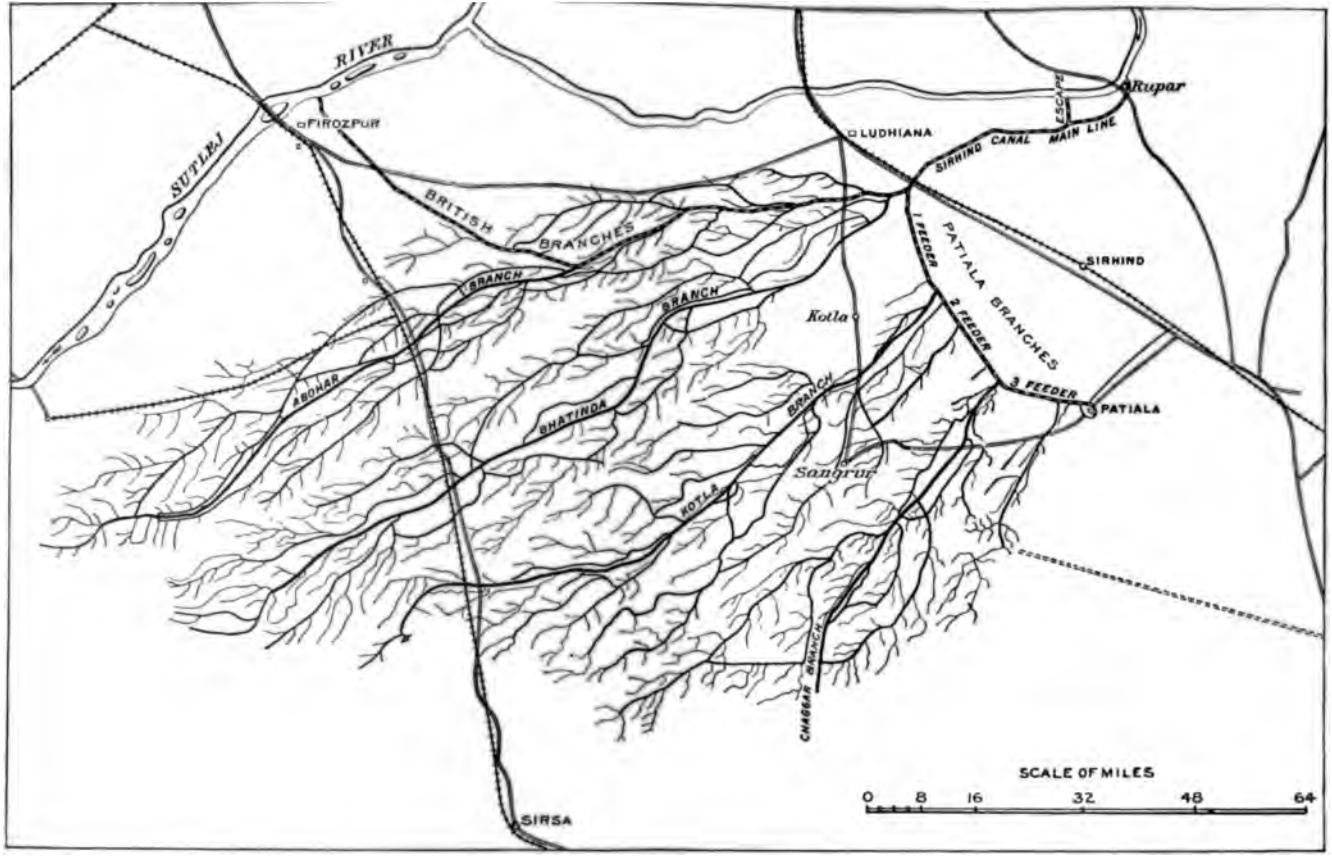
[a] Smith, Col. Baird, Irrigation in Italy, London, 1856, vol. 1, p. 256.

A project was submitted in 1862, and in 1865 the British Government decided that any canal constructed here should be devised irrespective of boundaries of British or native States. In 1868 the project was vigorously pushed, the size of the main channel was increased, and the head-works were moved 15 miles down the river to a point very near Rupar, and in 1869 the works were actively commenced.

This project (Pl. VIII) comprises a main canal from the Sutlej supplied by a masonry diversion wier. The length of this main channel is 41 miles. Of the branches, the eastern ones irrigate native State lands and are called the Pattiala branches; the remaining or western branches are known as the British branches. The heaviest portion of the work is in the first 10 miles, where the line crosses many hill torrents draining into the Sutlej. The head-works are, like those of the Ganges and Jumna rivers, situated at the point where the river emerges from the hills through a rocky bowlder channel, and where the general fall of the country is over 8 feet per mile. The maximum depth of the cutting through the spur at the head near the town of Rupar is 45 feet, and the average depth of cutting in the first 7 miles is 28 feet. The drainage in places is passed over the canal by masonry superpassages, while one torrent is diverted into the river by a cut terminating above the head-works. At the forty-first mile the main canal ends and the two branches diverge. Three miles below the bifurcation the British branch is again divided into the Bhatinda branch, 100 miles long, and the Ubohar branch, 125 miles long. On the Pattiala side the main feeder is divided into three sections by the diversion of the Kotla, Gagger, and Choa branches, respectively 90, 56, and 25 miles in length. The end of the feeder is the junction of the Choa and Pattiala branches, the latter being 6 miles long and terminating at Pattiala.

The principal works of interest on the line of the Sirhind canal are the head-works at Rupar, the superpassage crossing the Siswan Torrent, which in time of flood discharges 20,000 second-feet, and the superpassage across the Budki Torrent, which in time of flood discharges 30,000 second-feet. The siphon for a drainage crossing at Hurron Torrent, though small, is likewise deserving of particular mention in its place.

The water supply of the Sirhind canal is less than was anticipated. The least discharge of the river ever recorded was 2,818 second-feet, while the average minimum discharge is 5,150 second-feet. The maximum discharge of the canal as designed is 7,849 second-feet, and the maximum flood discharge of the river has been as great as 100,000 second-feet. The rainfall over the irrigable area varies between 10 and 35 inches per annum, and during the autumn crop is from 1 to 6 inches. The gross area commanded by the canal is 4,558,602 acres, of which 1,170,000 acres are irrigable. During the autumn crop of 1901 only 406,805 acres were irrigated, of which 161,967 acres were double cropped.



SIRHIND CANAL SYSTEM.

The total length of main canals is 41 miles and the total length of main branches 538 miles, while there are 4,636 miles of principal distributaries. The total outlay on this canal to the end of 1901 was $19,663,000, and since the canals were opened the net annual revenue has constantly increased, until in 1901 it amounted to 4.7 per cent. In the year under consideration the duty per second-foot in the autumn season on the supply entering the canal head was 108 acres, or $113, and on the supply utilized it was 110 acres, or $121. The average water rate per acre irrigated was 95 cents, the working expenses being 40 cents per acre, and the cost of establishment was 15 cents.

CHENAB, BARI DOAB, AND WESTERN JUMNA CANALS, PUNJAB.

As before stated, these three canals are among the oldest and best paying of their kind in India. In 1351 Feroze Shah constructed the first channel where the Western Jumna canal now exists, and at different periods up to 1817 the works were reconstructed and utilized. In 1817 Captain Blaine prepared to restore them. The supply of the Western Jumna is derived from the Jumna River at a point where it leaves the Sewalik Hills, where the fall is great and the bed composed of shingle and bowlders. On the opposite bank the Eastern Jumna heads at nearly the same place. In 1870 permanent headworks, distributive and drainage works, were constructed to replace the old ones, and a little later the main canal was almost entirely realigned. At the end of 1878 the total receipts since the works were taken in hand by the government had exceeded the working expenses and interest on the capital by $12,500,000, or about four times the first cost of the work. The total length of the main canal and branches in 1901 is 391 miles, and there are 2,210 miles of distributaries. The area irrigated is 870,500 acres and the maximum discharge of the canal is 6,350 second-feet. The total expenditure on this work to the end of 1901 was $10,730,000, and this earned revenue of 9.1 per cent. The gross receipts in that year were $835,000, and the gross outlay $325,000, the net revenue being $510,000.

The Bari Doab canal derives its source of supply from the Ravi River, and commands 1,641,660 acres of land between the Ravi and Bias rivers. In 1633 the Shah Jehan construct d the first canal in this neighborhood. The project for the new canal under British rule was first reported on in 1850, when the works were commenced. In 1856 they were revised, and water was admitted to some portions of the canals in 1859. In 1874 the works were decided upon as now constructed, and were estimated to produce a profit of 8.8 per cent. Recently a considerable amount has been expended in the construction and improvement of falls and rapids. The total outlay to the end of 1901 was $14,115,000 and the interest in that year was 12.9 per cent on the capital outlay. The maximum discharge of the canal is 6,500 second-feet, and the area irrigated 849,074 acres. There are 369 miles of main canals and branches and 2,725 miles of distributaries

The Chenab Canal is diverted from the river of that name, and commands 2,910,470 acres. It consists of 430 miles of main and branch canals and 2,059 miles of distributaries. To the end of 1901 its cost was $11,111,000, when it earned 14 per cent interest on that outlay. In the same year it irrigated 1,384,046 acres on a maximum discharge of 10,474 second-feet.

SIDHNAI CANAL, PUNJAB.

Estimates for a permanent inundation canal from the reach of the Ravi River were submitted in 1875 by Mr. E. C. Palmer. In this project the head of the canal was located at the top of the straight reach called the Sidhnai. Owing to bad alignment (as Mr. Palmer's project followed a low depression for many miles), the position of the head-works was abandoned, and a new site selected at Tatyraj, where the section of the river is 770 feet across and the banks consist of stiff brown clay.

The maximum discharge of the river is 18,000 second-feet, and is not likely to be exceeded. Gage records show that all idea of the construction of a perennial canal from this part of the river must be abandoned, as twice since 1875 the Ravi has been absolutely without flow during the cold season. As constructed, the only masonry works on the canal besides the head-works are the bridges and the heads of distributary channels. The area commanded is about 381,000 acres. Of this the present works provide for the irrigation of 194,900 acres. The duty was assumed to be 60 acres per second-foot, and the discharge of the canal was placed at 800 second-feet. The rainfall on the irrigated area has averaged 5.9 inches per annum. When the canal project was reported on in 1883 most of the country was covered with jungle to within about 3 miles of the river. This jungle consisted of coarse grass, brush, and tamarisk. The crops now grown on this land during the summer season are sugar cane, indigo, rice, cotton, and millet, and during the autumn season wheat, barley, turnips, and lentils.

On the line of the canal no drainage or protective works are required except one or two very insignificant ones. At first the canal was only excavated to half width, but all the masonry works were constructed of full width. As finally aligned the canal leaves the Ravi River at right angles and runs straight for 2,000 feet, where a long curve commences, ending at 3½ miles. It then keeps along the divide to Chauparata, whence it runs mainly in the bed of the old river Ravi. There are four main distributaries and six minor ones.

The head-works consist of a regulator with 8 sluice openings of 10 feet each. The curtain walls of the regulator and river banks are founded on wells 10 feet below the present river bed. Wells were [illegible]ted in preference to concrete, though they are more expensive. [illegible] was not certain that the latter could be put in 10 feet below the

bed. The weir consists of a wall 750 feet long, founded on concrete in the center and on wells for 20 feet from each bank.

The maximum discharge from the canal is 2,452 second-feet, the bed width of the main canal is 80 feet, the depth of water 5 feet, and the velocity of flow 1.85 second-feet. The discharge of the river varies between nothing at extreme low water and 18,000 second-feet at maximum flood.

The total cost of this work to the end of 1901 was $620,000. The net receipts for the same year amounted to $34,500, or 5.8 per cent on the capital invested. The water rate charged per acre irrigated during the autumn crop was 62 cents and the duty during the same season was 85 acres or 857.

THE SOANE CANALS.

Like the Sirhind canal in the Punjab, the Soane system in Bengal may be taken as an example of the most recent practice in the construction of a perennial canal system. The Soane canals are included in one system heading at a common point and having a common diversion weir. They consist of two main lines, one flowing from each bank of the Soane River. The Soane River is a tributary of the Ganges, rising in the central plateau of India and having a course of about 350 miles through the high country. Near Rhota it breaks through the hills, which at this point are 2,100 feet above the sea, whence it flows northeasterly for 75 miles through the Gangetan Plain to its junction with the Ganges near Arrah. In the plain it flows through the districts of Shahabad on the left or west bank and Patna and Gaya on the east bank. These are among the most fertile and highly cultivated districts in Bengal, densely populated and studded with ancient cities. The successful operation of the Soane canals is largely due to the acreage which is cultivated during the autumn season.

The works of the Soane canal were first undertaken by the East India Irrigation Company, but given over to the Government when scarcely any work had been done. The scheme was originally proposed in 1853 by Lieut. C. H. Dickens. A plan to utilize the larger portion of the volume of the Soane was, however, amplified by the same officer in 1861. In 1862 the secretary of state approved of the project, and after discussion by Sir A. Cotton and Colonel Rundall it was forwarded for the approval of the Government in 1864. In addition to the features now existing it was proposed in the original project to construct reservoirs in the hills south of Rajmahal to supplement the available discharge of the river. This part of the scheme was considered too expensive, however, and the plans were changed. In 1869 the work was undertaken by the Government. It was estimated to give a net profit of 12½ per cent on the outlay. In 1871 it was decided to reconstruct the slope of the canal, as the supply of water was not as great as had been anticipated.

The catchment basin of the Soane above Dehree, where the head works are situated, is about 22,000 square miles in area, and in flood the river discharges 750,000 second-feet, though the maximum flood provided for is 1,250,000. For about 40 miles below the diversion weir the floods seldom overtop the river banks, but below that point to its junction with the Ganges it is almost deltaic in character, considerable overflow taking place. To about this point the canal follows the bank of the river rather closely, after which it diverges and follows the high ridge between the Soane and Ganges.

The diversion weir across the Soane is at Dehree, a point 25 miles below where the river leaves the Kymore Hills, and is the longest weir in one unbroken length of masonry that has ever been constructed, being 2½ miles long and 8 feet high. In high flood the river rises 8½ feet above the crest of the weir. The main western canal (Pl. IX)

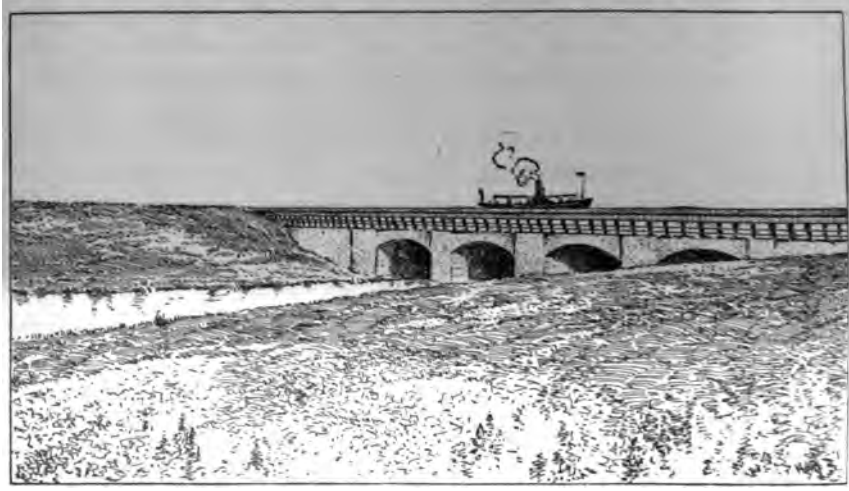
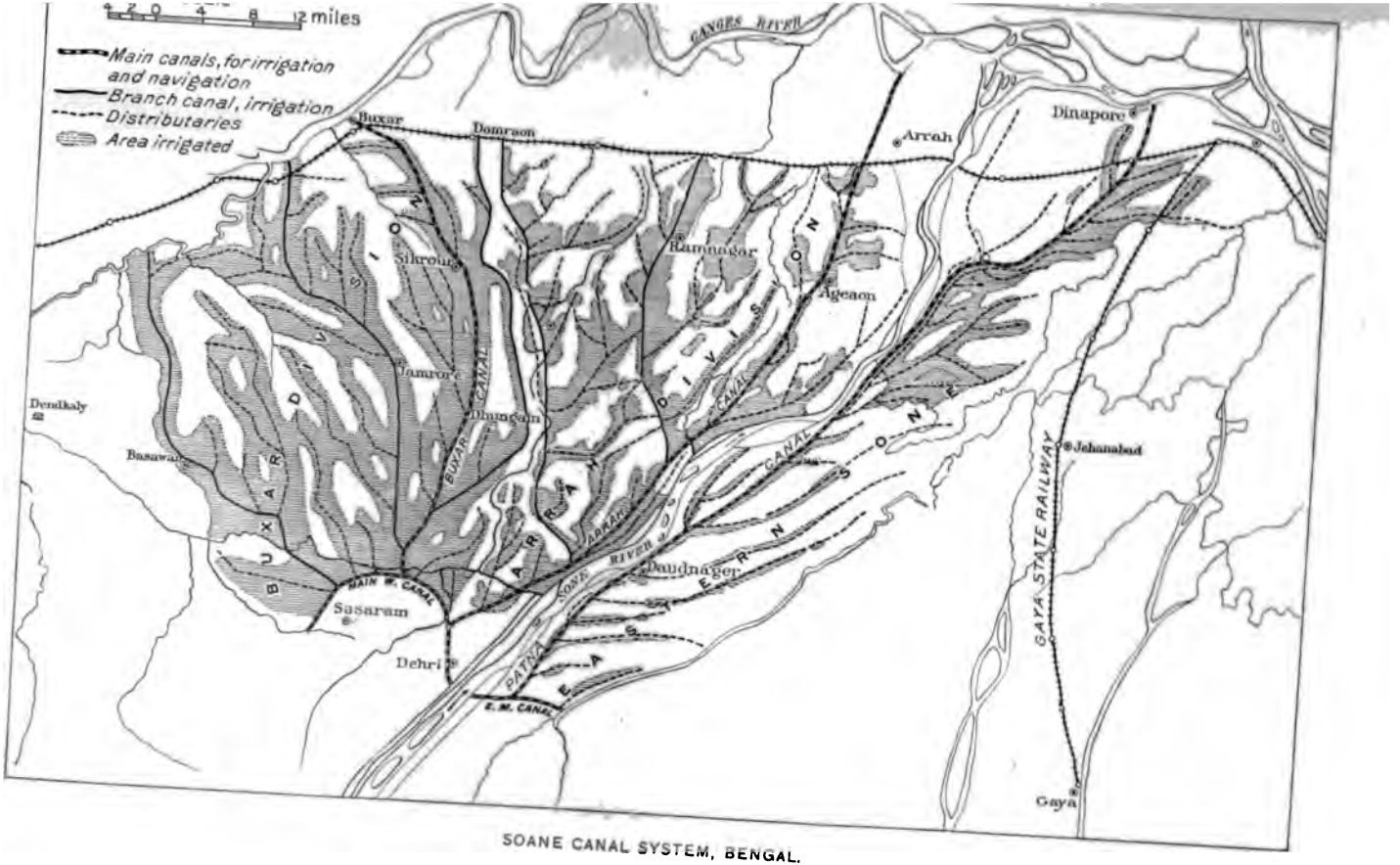


FIG. 8.—Thora Nulla aqueduct, Soane canal.

takes off from the weir on the west bank where it encounters a rather deep cut. It crosses the Kao Torrent by a large siphon aqueduct in the ninth mile and similar drainage channels in the seventeenth and twenty-first miles. The Arrah canal leaves the main western at the fifth mile and follows the bank of the Soane to the thirty-third mile, where it leaves it and passes close to the town from which it takes its name, tailing into the Ganges. On this line are 13 locks with an aggregate fall of 161 feet. The Buxar canal leaves the main western at the twelfth mile and is almost straight from that point to the Ganges at Buxar. The total fall in this line is 153.75 feet, and in the twenty-ninth mile the canal crosses the Thora Torrent (fig. 8) on an aqueduct with 4 arches, each of 30-foot span. The other main canal of this system, the main eastern, takes off from the Soane weir on the eastern bank opposite to Dehree and is 7 miles long, its termination



SOANE CANAL SYSTEM, BENGAL.

being at Poon Poon Torrent. The Patna canal leaves the main eastern at the fourth mile, and, after following the river bank for 60 miles, is diverted to the ridge and tails into the Ganges near Patna. It was estimated by F. T. Haig, R. E., when chief engineer, that these canals would pay both interest and working expenses on the outlay until 1887, when it was expected that they would return a net profit of 4½ per cent.

The important feature of the head-works is the mode of construction of the weir, the automatic action of the scouring sluices, and the arrangement of regulating gates. These are elsewhere described in detail in connection with the subject of automatic scouring sluices, on pages 121–122, 127–128. The weir and principal works were designed by H. C. Levinge, chief engineer of the East India Irrigation Company.

The minimum discharge of the Soane River at Dehree is 5,260 second-feet in summer and 1,870 second-feet in autumn. The maximum discharge of the canals is 6,350 second-feet, of which the main eastern canals discharge 1,850 and the main western series 4,500 second-feet. The average rainfall upon the area irrigated is 41 inches. The gross area commanded by the entire system is 1,733,509 acres, of which 1,016,400 acres are irrigated. There are 367 miles of main canals and 1,217 miles of distributaries. The average discharge utilized in the autumn of 1901 was 3,300 second-feet, and the duty performed during the autumn was 110 acres per second-foot of the supply utilized. The water rate per acre was 85 cents. The total length of village channels or minor canals is 1,525 miles; the total number of outlets for distribution of water is 6,000, the area irrigated per outlet being 93 acres.

In the Arrah division, Mr. W. A. Inglis, the executive engineer, calculated the supply of water spread over the country was equal to an effective rainfall of 5.7 inches. On the assumption that one watering of 6 inches in depth is given every fifteen days, 1 second-foot of discharge should irrigate 60 acres if the outlet were constantly open, or 40 acres if the discharge outlet were open for only ten out of fifteen days. The cost of repairs to the head-works in 1890 was about $16,000 per annum and the cost of maintenance exclusive of head-works about $81,000. The charges for silt clearances amount to $30,000 per annum, the total amount of clearances being 10,850,000 cubic feet and the rate about $3 per 1,000 cubic feet. The silt clearances were made by means of large steam dredges. The total cost for weed clearance was $1,600 in 1888, and the mileage rate or cost of repairs varied from $30 per mile on distributaries to $65 per mile on smaller branches, $211 on larger branches, and $2,800 on the main western canal.

The following is a statement of traffic on these canals for the year 1888. There were 218 miles of canal open for navigation. The toll-

age receipts from private boats amounted to $12,000; on government boats $1,400, and on rafts $3,500. These with minor items make the total receipts from tollage $18,600. The maintenance charges, including navigation establishment, were $11,800 and the net revenue from navigation was $6,800. The total number of cargo boats was 4,547; of passenger boats 530. The total tonnage of these boats for cargo traffic was 71,243 long tons and for passenger traffic 12,437 long tons, and the total ton-mileage was 4,635,000 miles. The estimated value of the cargoes was $1,785,000 and the passengers carried numbered 46,170. There were estimated to be 3,089,000 cubic feet of rafts, valued at $107,000. The tollage receipts per ton-mile on boats was 3 mills, and tollage on rafts per hundred cubic feet was 11 cents.

The total outlay on the Soane system to the end of 1901 was $17,558,000 and the revenue in 1901 was $175,000. The gross receipts were $370,000. There was a net revenue, after deducting all working expenses, of $162,000, or 1.8 per cent, on the capital outlay.

CROSS SECTION, SLOPE, AND ALIGNMENT.

In designing a canal system the Indian engineer, having decided on the location of the head-works and ascertained the source of supply and the area and location of irrigable lands to be served, next considers the proportion of width to depth of his channel, the cross-sectional area being fixed by the supply of water to be discharged at any point. On the Western Jumna canal the proportion of depth to width is that which the Jumna River has in the course of years formed for itself, found by trial to be about 1 on 13. On the Bari Doab the proportion fixed in construction was 1 on 15, and on the Sirhind 1 on 14. In the case of the Nira canal, which is nonnavigable and of a smaller capacity than those just described, the proportion is much less, the depth being 7½ feet and the bottom width 23 feet. On the Soane the main western line has a depth of 10 feet and a bottom width of 100 feet, or a proportion of 1 on 11. The Betwa, which, like the Nira, is nonnavigable, is relatively deeper than the larger canals, being 5 feet deep to a 15-foot bed width on some branches, and on others 6 feet deep to a 30-foot bed width. The proportion first given is such as will apply only to canals so great as to correspond in their general characteristics to large rivers.

The side slopes of the canal (fig. 9) are generally arranged according to the facilities for excavation, and are such that the ground will stand at a natural angle. In the soils in which the canals are generally excavated in Bombay the side slopes are usually 1 on 1½ on the inside and 1 on 2 on the outside. The matter of fixing the cross section has been a difficult one to solve on account of the conflicting conditions of the supply of water required and velocity permissible. This is fixed

the liability to growth of weeds, the deposit of silt, or the destruction of the banks by erosion.

Having determined the quantity of water, fixed the proportion of width to depth, and ascertained a maximum for both, the slope of the bed becomes one of the most important remaining problems in the design of the canal. If the slope be too great, the bed of the canal and its sides will be eroded and the integrity of the masonry and other structures endangered. If it be too small, a larger section of channel will be required to discharge a given quantity of water, and additional works, as falls, may be necessary to overcome the excess of surface slope in the country. The growth of weeds and aquatic plants and the deposit of silt will become a troublesome evil. As it is difficult to avoid both extremes, a compromise has generally to be made. It is, perhaps, well to err on the safe side and give to the bed the greatest

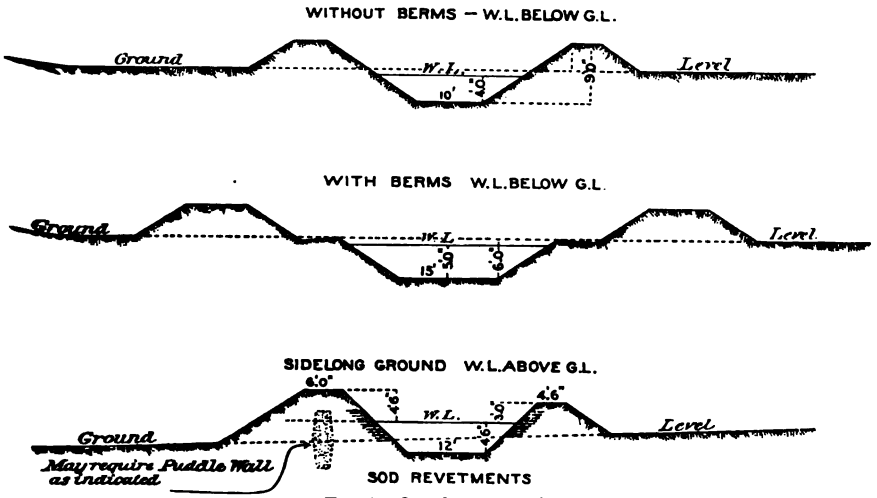


FIG. 9.—Canal cross sections.

slope apparently desirable. If this slope should prove to be too great or the fall of the country too rapid, the difficulty may be remedied by introducing falls and rapids in the channel to diminish its general slope and concentrate the loss of grade in a few places. In different soils and in different canals the velocity given for the prevention of the growth of weeds and the deposit of silt differs largely, but it has been found generally that the minimum velocity is about 1½ feet per second. According to American experience this is too low, as we usually consider that 2½ or 3½ feet per second is the minimum. In India the maximum for ordinary soils rarely exceeds 4 feet per second. In America it is often much higher.

One of the greatest difficulties encountered in India in determining the velocity, slope, and cross section to be given to a canal has been the introduction of navigative works. These are generally antago-

nistic to the requirements for irrigation purposes only. The velocity of the current in navigable canals must be low in order to permit traffic in both directions. In the Ganges canal, with a bottom width of 170 feet and a 7-foot supply, a slope of 14 inches per mile has been given in the sandy soil of the upper reaches, and the resultant velocity is such that the current has just ceased to cut the banks and to deposit silt. In the first portion of the canal where the bed is in gravel and bowlders the fall is 24 inches per mile. From there on the slope of from 15 to 17 inches has been found to be too great, the water having done much damage to the banks. The larger portion of the reach of 20 miles from Hardwar to Roorkee is extensively riprapped now and the engineers are continually adding a lining of bowlders to the bed and sides of the canal.

The velocity of 3 feet per second, which was originally given to the Soane canal, caused much damage by erosion and had to be remedied. Colonel Anderson, R. E., made some interesting remarks on this subject in the Roorkee Manual, among which were the following:

> Where the fall of the country is tolerably uniform the slope of the bed of the main channel must be less than that of the branches. This, again, must be less than that of the distributaries and minors, the object being to secure, as far as possible, a uniform velocity, so that the matter carried in suspension may be carried on from the head and deposited over the irrigated lands. At the head of a canal it is sometimes desirable to reduce the width in order that with an increased depth the velocity may be the same as that in the channel lower down.

He says that the accumulation of silt in the main channels is a serious impediment to obtaining a supply of water until the crops are mature, and their clearances are enormously expensive. If the silt can not be carried to the fields, it is a step in advance to prevent its accumulation in the main channel. It is easier to clear out the minor branches without cutting off the supply from the main river. Escapes are introduced at intervals in all canals for the control of the discharge of water and to facilitate silt clearances and as a prevention of its deposit.

The following interesting observations were made by Major Crofton in his report on the Ganges canal relative to velocities of current: Where the current seemed to be perfectly adjusted to a light, sandy soil the velocity of the surface was found to be from 2.3 to 2.4 feet per second and the mean velocities, using 0.80 as a coefficient, were found to be 1.85 to 1.93 feet per second. In one place, where silt was being constantly deposited, the mean velocities were from 2 to 2.3 feet per second. On the same canal in very sandy soil, with nearly a full supply of water, the maximum surface velocity was found to be 3.08 and the mean velocity 2.49 feet per second. In one of the distributaries, where the soil is sandy with a fair proportion of clay, the mean velocity was 1.93. Here silt was deposited but no weeds grew. On the Western Jumna canal Colonel Dyer, R. E., found that silt was

eposited with mean velocities of from 2 to 2¼ feet, and in sandy soil .7 feet per second was the highest mean velocity for noncutting. ackson's and Neville's formulae are those most usually employed in he determination of velocities and corresponding cross sections. In esigning the proportion of excavation to embankment and the width f berm, several interesting but involved formulae are employed by he Indian engineers, of little service, however, as guides to the lesigners of American canals.

Great care and judgment must be exercised in the alignment of an rrigation canal. Any change of direction causes a loss of velocity, and the slope should be changed if it is essential to introduce a curve. The water drawn into branches and distributaries loses velocity in passing through the head-sluices unless they possess the full water-way of the channel, and due allowance should be made for this by adding to the slopes at the heads of branches. The Indian engineers have always deemed it essential in designing their canal systems to make a thorough and detailed survey of the country to be irrigated, so that the most perfect alignment and command of the lands can be obtained. Trial level lines and careful transit surveys are run, after a rough survey has been made, and the whole is shown on a large scale contour map. A complete delineation of the drainage of the country is one of the primary objects, as is also the direction of the drainage outlets and the interfluves. The nearer the line of the canal approximates to the summit of the watershed the better will be the alignment, as the interference with the surface drainage of the country will then be the least possible. In encountering cross drainage provision must be found for its safe passage, and unless the streams are very small they should never be permitted to enter the channel. The canal should always be made to tail into some drainage line or river, so that the surplus may not be lost, and in order to insure a sufficient scour it is deemed advisable to increase the velocity at the end. When practicable all embankments are formed by ramming the soil in thin layers. Where the channel runs through sandy soil the beds and banks should be covered by an impervious puddle.

Great care has been used to fix the permanency of all transit points and bench marks, etc., on the surveyed lines of canals in India. On the outer edge of the berm are placed masonry mileposts, with smaller masonry pillars every one-fourth mile, while on the inside white-washed stones are laid into the ground every 100 feet. At frequent intervals large substantial masonry benches are established.

HEAD-WORKS.

The head-works of canals are usually located at the points where the rivers emerge from the hills, in order to obtain a sufficient command of land and allow the canals to reach the summits of the interfluves with the shortest possible length of diversion line. In India,

owing to the great volume of flood water required to be passed over the diversion weir, it is necessary to have an extremely wide waterway, and it is usual to locate the weir in a relatively wide portion of the channel. If the only consideration in the location and construction of a weir was the raising of the water of the river to the level of the canal bed, in order to obtain the shortest possible diversion line, the most favorable location would be in the lower courses of the river, where the fall is gradual and the banks shallow. Such an obstruction of the bed in these localities would, however, raise the surface of the water in freshets, rendering necessary the construction of artificial embankments and other protective works, and would be extremely objectionable. A rock bed, though a great advantage and always to be preferred, is not considered an indispensable requisite in constructing weirs.

Several great Indian weirs have been thrown across rivers whose beds consist entirely of pure sand, reaching far below the foundations. In such constructions the chief requirement is a strong apron beneath the weir to break the fall of the water and prevent the foundations from being undermined. Prof. George Davidson says:

> In order to reduce the first cost of construction it has become a custom in America to build bridges and dams across streams at the narrowest points available, or to contract the streams for that purpose. This frequently involves great difficulty to the engineer in laying the piers and abutments, and also brings in an additional danger by adding to the scouring effect of the water on a contracted channel; it also produces the evil effects by the formation of shoals below the scouring-out channel. The proper location for such works, especially across rivers with unstable banks, is in the broad reaches of the stream, where the depth of the water is less and where a bar has been already formed across the river by natural causes.[a]

A dam across a river is analogous to a bar, and should be located and treated as such. If this is placed at the broadest part of the stream the cost of construction may be increased, but not necessarily. Instances of the location of weirs in the broadest reaches of rivers may be cited in the case of nearly every weir constructed in India. The weir at the head of the Ganges canal occupies the full width of the channel; those of the Bari Doab and of the Soane are thrown across at points where the width of the river is an average. The weir at Okhla, at the head of the Agra canal, is also constructed in a broad reach.

The head-works of Indian canals consist essentially of the weir across the river by which the level of the water is raised and its flow checked; of a set of scouring sluices placed in the weir at the end adjacent to the canal head, the object being to create a constant flow past this head, thus preventing and carrying off any excessive deposit of silt, keeping as they do the course of the main channel of the river close to the canal head; and, lastly, of a regulator across the head of

[a] *Davidson*, Prof. George, Irrigation Works of India. U. S. Senate Doc. No. 94, Forty-fourth *Congress*, Washington, D. C., 1875.

canal channel, by which the proper quantity of water is admitted .. In a few cases, as those of the Ganges and Jumna canals, where canal is taken from a branch of the river, a permanent dam is ·wn across this channel only, the water being diverted to it by ns of the river-training works.

WEIRS.

he weirs employed are of various kinds, but are always con-cted substantially of masonry and are well founded. They may on solid rock foundations and be nearly vertical with an over-onto a rock bed, or flat and low, founded on wells in sand, with rtical overfall onto an apron of masonry; or they may be similar ne latter with the exception that instead of the vertical overfall downstream slope may be constructed of loose-packed rock on a ; slope of, say, 1 on 15 on 20. Only rarely are porary weirs constructed ply of loose bowlders. two great classes of rs are solid weirs, such hose above indicated, or n weirs, in which the ob-ction is temporary, as lles or removable sluice s.

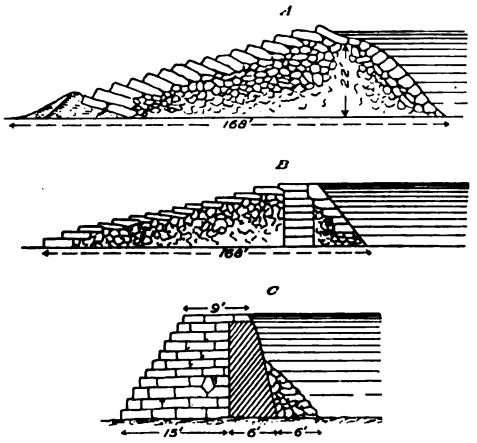


FIG. 10.—Three ancient weirs.

he antiquity of weirs very remote. The first t weir, that at Tulkad, he river Cauveri, is said have been constructed one Madwa Rou, A. D.

Many others are said to belong to the sixteenth century, while rs are of intermediate dates. The new works of the Indian ves are of minor importance, with the exception of the Poorniah nnel, constructed in the early part of this century to lead the ed waters of the Cauveri River to Misau. Rough stone weirs t at the heads of most of the channels in Misau. These raise the er level to the required height, the lowest being 7 feet and the est 25 feet. The canals are for the most part supplied with lating sluices at their heads and with escapes for getting rid of d waters.

he accompanying illustration (fig. 10, A) shows the section of a ve weir constructed early in the present century, the breadth of ch, parallel to the course of the stream, was 168 feet. This weir sisted of a mass of rubble and large stone, the front face formed tones 1½ by 1 foot, while the apron was composed of rough stone

blocks 9 by 3½ by 2 feet, laid in uneven courses. All the interstices were filled with large rubble. Repairs were first made in 1842, and thereafter were carried out on a slightly different plan, (*B*) the general section being retained. The repaired dam appeared as here indicated. These illustrations give a fair idea of the attention given by the natives to this class of work and indicate the fallacy of trusting to size and position of the material instead of to the homogeneity of the work. Notwithstanding the employment of large blocks of stone and skillful application of material the dam was breached five times between 1842 and 1863.

A later development is indicated in the cut given of the Muddur weir (fig. 10, *C*). General Greene retained the native section of this weir, but corrected its chief failing by building an impervious brick and mortar face against its upper side. The natives, with the object of decreasing the depth of water flowing over the weir in flood times, carried the work in a curved line, its general direction tending upstream. The length of the weir was nearly double the actual breadth of the river, and its crest was at different levels in different places; the part next the head sluice being invariably lower than the rest relieved the head of water pressure against it during flood. All these features, shown by experience to be desirable with the native works, are so many defects with the solid masonry work now adopted. The regulators in the old works at the heads of canals were mostly constructed of rough stone posts, the openings between which were stopped with rough timber and fulfilled their objects in an imperfect manner.[a]

In regard to the two main designs adopted by modern practice for weirs, namely, the open and the closed or solid weir, the advantage of the latter is that it is self-acting and if well made requires no repairs or maintenance. Its first cost, however, is greater than that of an open weir, and it interferes with the regimen of the river, causing deposits of silt above it and perhaps making the river seek another channel. The open or scouring sluice weir interferes but little with the normal action of the river. The scour produced by opening the gates prevents the deposit of silt and its first cost is less than that of the closed weir. Another form of weir, the best examples of which are to be found in the barrages of France, consists of a weir open the whole width of the channel, the object being to prevent in time of flood the water being backed up, thus submerging valuable property above the weir. The obstruction in the river channel may be entirely removed by opening the gates the full width of the weir.

The ordinary weir consists of a masonry floor acting as an apron properly founded and carried across the entire width of the river flush with the level of the bed and protected from erosive action by curtain walls up and down stream. On a portion of this is constructed the upper work, which may consist of a solid wall and part masonry

[a] Sankey, Maj. R. H., Roorkee Professional Papers, No. 141, Roorkee, India.

rs, the interstices between the latter being closed by some tem-
ary arrangement, thus creating the scouring sluices. Weirs proper
in no instance to be looked upon in the light of storage works.
ey may for a trifling period during the dry season answer that
pose, but the irrigation from them depends in all cases on the
tinual flow of a small quantity of water or upon an auxiliary sup-
from storage waters situated higher up. In speaking of the mode
onstructing low diversion weirs with long slopes, Col. Baird Smith
s:

. rivers with beds of pure sand and having slopes of 3½ feet per mile such weirs
be constructed and maintained at a very moderate expense, and the elevation
ne beds of the rivers on the upper sides of these weirs to the full height of the
vns is an inevitable consequence of their construction and no arrangement of
er sluices has yet been effective to prevent this result.

n regard to founding these structures on wells, he further says:

ı pure sands acted on by currents due to a fall in the river bed of 3½ feet per
e, and exposed to the action of floods from 12 to 15 feet deep, well foundations
ront and rear of 6 feet in depth have been proved by experience to be safe."

ıs a general rule the masonry apron should have a thickness equal
one-half and a breadth between three and four times the vertical
ght of the weir forming the obstructive part of the dam. The effi-
ıcy of the dam depends upon the construction and careful main-
ance of the apron. In time of freshets the water backed against
toe of the weir has a protecting effect on the apron by producing
ater cushion, and as the flood rises the height of fall from the weir
st gradually diminishes, and in a flood of 16 feet over an ordinary
r it wholly disappears, leaving scarcely a ripple on the surface to
icate the existence of the masonry mass below.
n the construction of weirs in rivers with sandy beds, wells may be
ısidered as the feature of Indian engineering. These are essen-
ly open blocks or cylinders of brick usually sunk in the bed of the
er at low stage and are protected by temporary sheet piling placed
ween their outer edges, while the intermediate spaces are being
ed in with concrete, thus forming a solid wall floating in sand, upon
ich is built the superstructure of the weir, scouring sluices, apron,
l retaining walls. Whatever the form of foundation, be it gravel
hardpan, solid rock or wells, the first portion of the weir con-
ıcted is the scouring sluices, which are carried on at the same time
h the regulators at the head of the canal. This order is pursued
ause after the construction of the scouring sluices the water in the
er may be diverted through them while the work upon the remain-
of the weir is progressing, and especially so that it may be passed
ough them when the closing of the weir is effected. The heaviest
d of water takes place through these scouring sluices, and in their
ıstruction the very best workmanship and material are required.

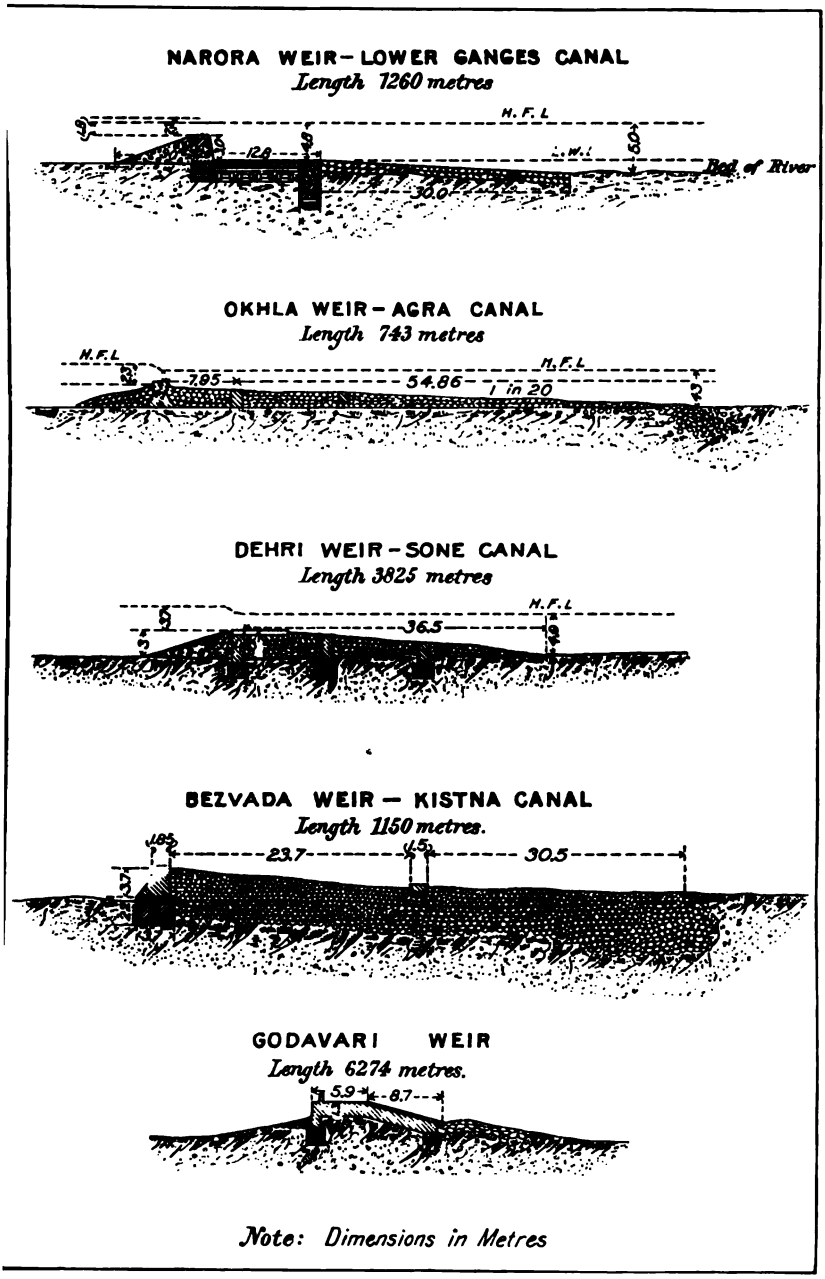
---

a Smith, Col. Baird, R. E., Italian Irrigation, London, 1856.

The weir may, if desirable, progress at the same time with the liminary works. The cross section of the weir is neither as lo as flat as that of the foundation and sluiceways. When the of the weir is effected the low water in the channel is diverted t the sluiceways, sand or other material available is carried acr last opening, foundations are built up as rapidly as possible, a superstructure closed.

Where a good rock foundation is obtainable in the bed of the close to the surface the weir is given an entirely different cross from that of weirs constructed of other material, and is built th out of the most substantial masonry laid in cement. In the some weirs, the overfall height of which is not great, the cross is made nearly vertical upstream, and a slight slope, perhaps 4 given on the downstream face, which is usually so curved as to away the flood water with the least shock to the dam. In the higher weirs of this character, or those over which great floods discharged, it is usual to make the downstream face nearly ve giving a sufficient top width and slope to the upper face to ins stability of the structure and bring the resultant line of pr within the middle third. The object of the vertical slope on the stream face is to give a clear overfall for the flood water. This on the water cushion formed by the construction of a subsidia placed some little distance below the main weir, and backs the up against its base. In all forms of overfall weirs liable to the shock of large floods it is customary to construct these sub weirs, some examples of which will be given in their proper In the location of such weirs, a broad reach of the stream is for the site of the main weir in order to reduce the height o passing over its crest; while the subsidiary weir is, if possible, in a narrower place so as to produce the greatest depth of w the toe of the upper weir. Scouring sluices of limited cross-se area are introduced in such weirs as these, their object being a clear channel immediately in front of the canal regulators.

Of weirs founded on wells in sandy rivers, that at the head Lower Ganges canal at Narora presents a peculiar type, bei stantially built of masonry and with a profile similar to that masonry weirs just described. This weir is constructed ent brick, chiefly because of the cheapness of the material at Nar consists of a wall 8 feet wide at bottom and 7 feet at top, the which is 9½ feet above the river bed. The upstream slope is while the downstream slope is nearly so. It is protected on th side by a quantity of loose rocks or bowlders thrown into t bed nearly flush with the crest. On the downstream side is a nearly 150 feet wide to receive the impact of the falling wate first 40 feet of this apron is composed of masonry resting on fo of shallow wells, abutting at its lower end against a row o



CROSS SECTIONS OF MODERN WEIRS.

ow this is a considerable depth of loose hand-packed bowlders ried out to the extreme toe of the apron.

'he total length of the masonry portion of this weir is 4,125 feet, luding the scouring sluices at the head of the regulator, which are feet long. The left end of the weir rests on an earth embankent a little outside of or beyond the river channel. This embankent is 1,000 feet long with an angle at the shoal end, and is carried up stream for some distance, thus protecting the low river bottom on t side from flooding. Detailed drawings of this weir showing its ss section, the plan of its foundations, and the arrangements of embankment and canal head are presented. (Pls. XI and XII l fig. 22.)

Another and very common type of weir founded on wells is that repented by the weirs at the heads of the Agra and Soane canals . X.) The weir at the head of the Agra canal, as first constructed, l too bold a cross section, and during several successive years the ver end or toe was carried away in time of flood. It has remained act ever since its reconstruction in 1875. This weir is without ndations of any sort, resting on the river bed. It consists of a ll of masonry 4 feet wide on top and a little wider at base forming e main crest line of the weir, the height of which is 10 feet above e river bed. From this crest the slope upstream is carried to a disce of 40 feet, and consists of large stones hand packed and laid y. The downstream slope is very flat, averaging about 1 on 20, and carried a distance of 26 feet to a point at which is constructed other masonry well similar to the first and resting on the river bed, line being parallel to the axis of the weir for its entire length. ne distance below this is a smaller well similar to the two previsly mentioned. The entire remaining portions of the weir consist large stone blocks dry packed, the walls acting as bars to prevent ir sliding.

This weir is 2,573 feet long from the right bank at the canal head, left wing resting on an island in the middle of the Jumna River. embankment 20 feet wide on top was carried thence to and across east channel and thence up the left bank of the river for some es. The scouring sluices are 139 feet wide, and are substantially nded on four lines of wells. In order to prevent the destruction of s weir by the action of flood waters, groins of a peculiar shape, called gator groins, are constructed on both the upstream and downstream es at intervals across the channel of the river and parallel to the rse of the stream. The object of these is to deflect as much water possible toward the right bank with a twofold object--first, the truction of an island which obstructs the channel just above the al head; and second, to aid the under sluices in sucking or draw- water toward them at low water, thus affording a sufficient disrge in front of the canal head.

The Soane weir (fig. 12) is similar to the Agra weir in gener[illegible] struction, but resembles that at the head of the Midnapore [illegible] more than any other. It consists of three parallel lines of ma[illegible] running its entire length and varying from 2½ to 5 feet in [illegible] The main wall, which is in the central axis of the weir, is 5 feet [illegible] and 8 feet high, and all three lines of walls are founded on wells [illegible] from 6 to 8 feet in the sandy bed of the river. Between these [illegible] is a simple dry stone packing. The upstream slope is 1 on 3, [illegible] downstream slope 1 on 12, and the total length of the lower slo[illegible]

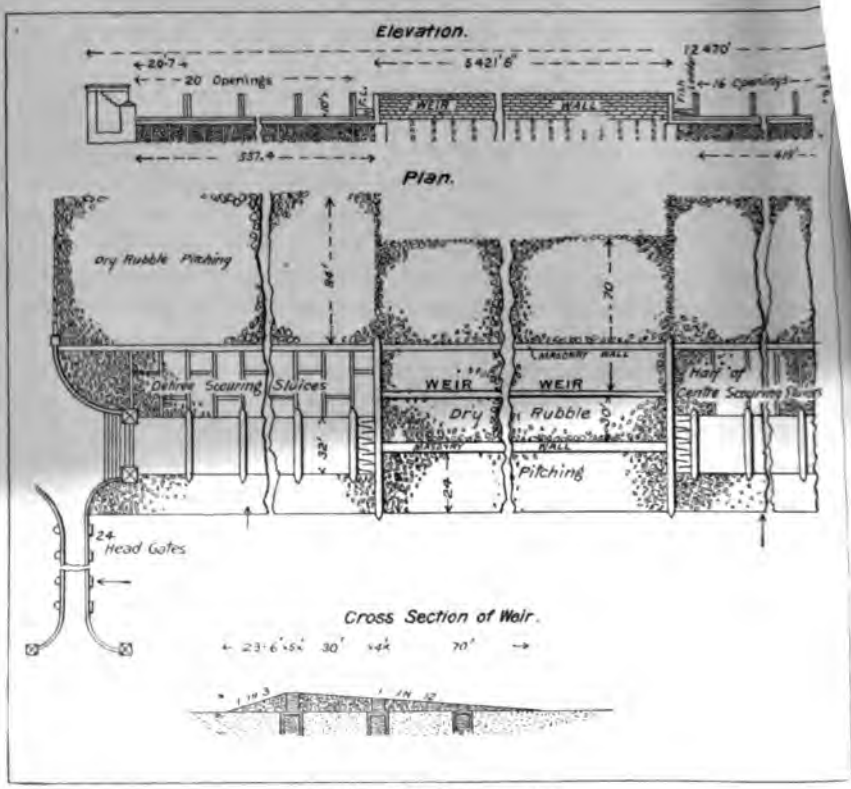


FIG. 11.—Plan of Soane weir.

94 feet. The total length of the weir is 12,470 feet, and it is 19.3 feet in height, including its foundations. On top, hinged to the lower edge of the crest wall, is a row of iron shutters (fig. 13), each 18 feet long and 22 inches high, which are supported by struts, so that when the river is low they increase the diverting height of the dam by 22 inches, and in time of flood they fall automatically, thus giving the flood a solid masonry crest over which to flow. These shutters are held in place by an iron rod hinged to their centers on the upstream side at about one-third of the height from the base.

The Soane weir (fig. 12) is similar to the Agra weir in g
struction, but resembles that at the head of the Midnap
more than any other. It consists of three parallel lines
running its entire length and varying from 2½ to 5 fee
The main wall, which is in the central axis of the weir, is
and 8 feet high, and all three lines of walls are founded on
from 6 to 8 feet in the sandy bed of the river. Between
is a simple dry stone packing. The upstream slope is
downstream slope 1 on 12, and the total length of the lo

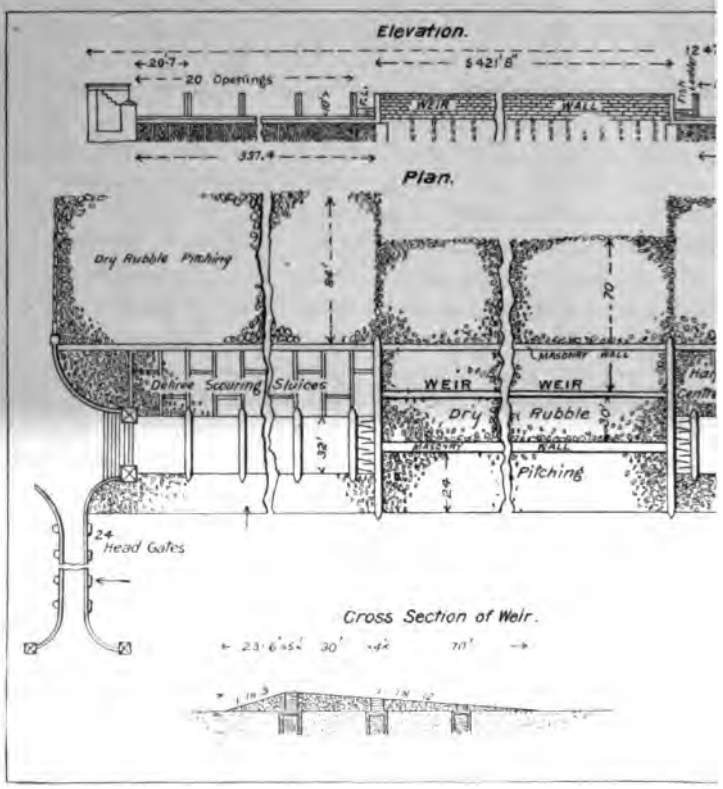


FIG. 11. Plan of Soane weir.

94 feet. The total length of the weir is 12,470 feet, and it
in height, including its foundations. On top, hinged t
edge of the crest wall, is a row of iron shutters (fig. 13),
long and 22 inches high, which are supported by struts, s
the river is low they increase the diverting height of the
inches, and in time of flood they fall automatically, thus
flood a solid masonry crest over which to flow. These s
held in place by an iron rod hinged to their centers on t
side at about one-third of the height from the base.

weir across the River Ravi (fig. 14) at the head of the Sidhnai represents a new and different type of construction. At the

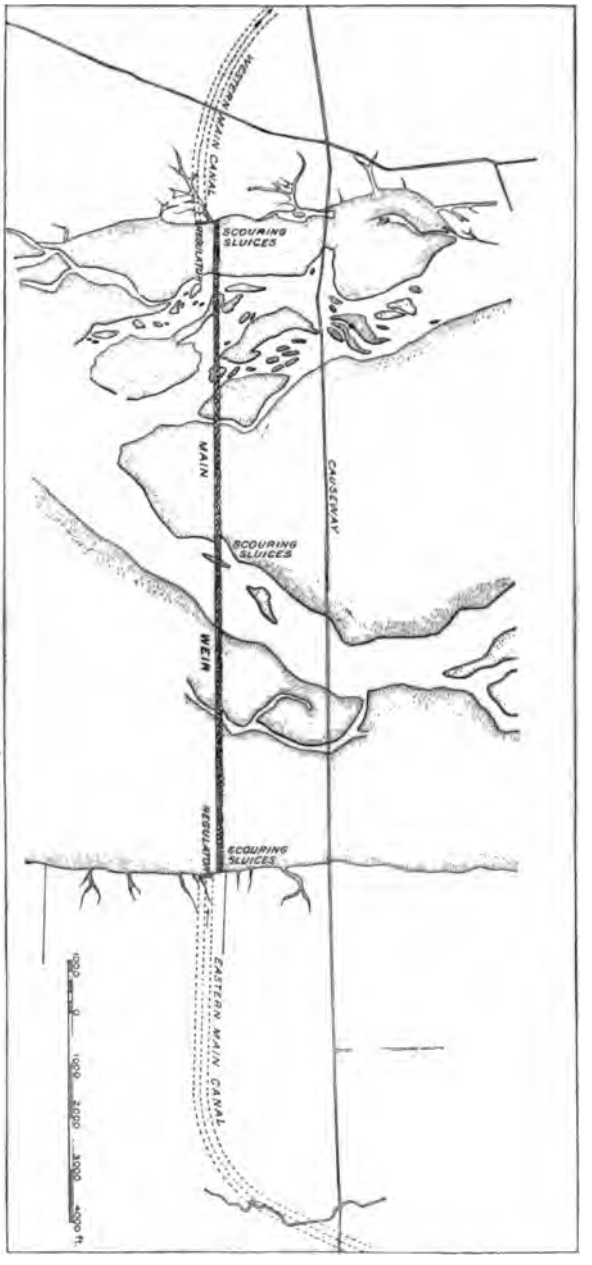


FIG. 12.—Plan of head-works, Soane canal.

where the weir is built (fig. 15) the river bed for 250 feet on the ank and 200 feet on the right bank gives a good clay founda-

ion for a reasonable depth below the top of the weir, but the central portion, 390 feet long, is of sand too deep to permit of carrying the foundation to the underlying clay. A trench was dug through this

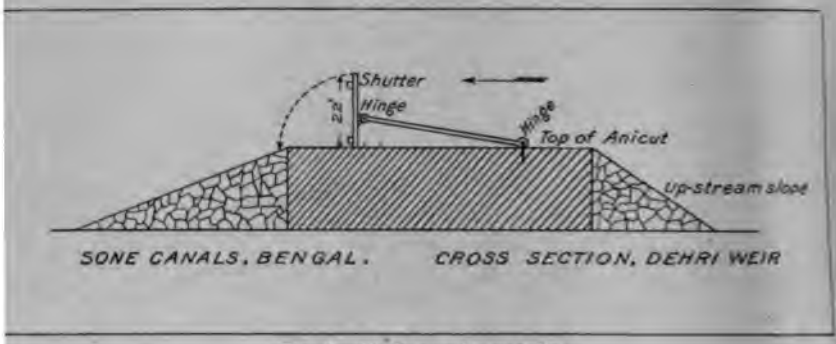


FIG. 13.—Shutter on Soane weir.

central sandy portion to a depth of 13½ feet below the crest of the weir, and for a distance of 400 feet, and sheet piles 10 feet long were driven into the sand as a protection for the foundation, and to prevent excessive percolation below the level of the weir. The highest recorded flood would pass 10 feet over the weir crest. The crest of the weir supports a row of wooden needles which are readily removable and are 7.5 feet long. They are placed between masonry pillars about 16 feet apart, thus increasing the effective diversion height of the weir by their length. This mode of construction is indicated in fig. 19, and the action of the needles is more fully described elsewhere.

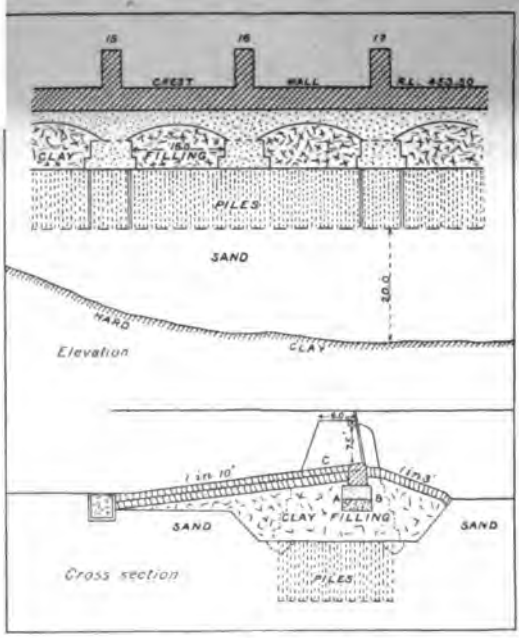
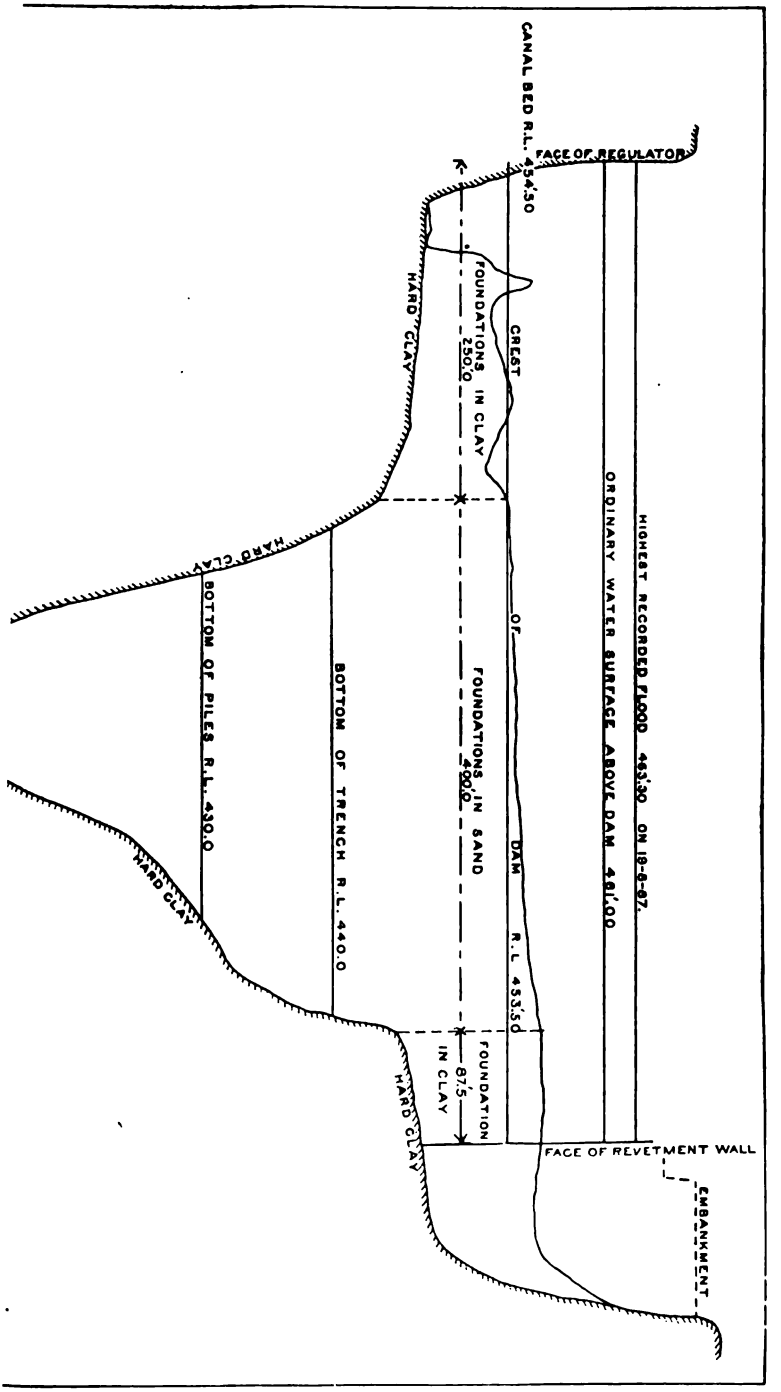


FIG. 14. Sidhnai weir.

Of temporary weirs, the most notable example is that at the head of the Ganges canal above Hardwar (fig. 18). At this point the bed of the river is composed of bowlders of various sizes to a considerable depth. The head-works of the canal consist of a number of separate structures extending up the river above the head of the canal proper

CANAL


HIGHEST RECORDED FLOOD 453.30 ON 18-8-97.
ORDINARY WATER SURFACE ABOVE DAM 451.00
FACE OF REGULATOR
CANAL BED R.L. 454.50
CREST OF DAM R.L. 453.50
FOUNDATIONS IN CLAY 250.0
FOUNDATIONS IN SAND 400.0
FOUNDATION IN CLAY 87.5
HARD CLAY
HARD CLAY
HARD CLAY
HARD CLAY
BOTTOM OF TRENCH R.L. 440.0
BOTTOM OF PILES R.L. 430.0
FACE OF REVETMENT WALL
EMBANKMENT

distance of several miles. The bed of the river is divided into several channels, the principal one being the Hardwar channel, from which the canal is diverted and into which the greater part of the water in the stream is trained by means of various works. The general plan of these works is given in the accompanying sketch. At the upper end of the bifurcation of these channels is a masonry wall or dam constructed across the left-hand channel, the object being to force the water toward the Hardwar or right bank. The Hardwar channel from this point on is protected and trained by means of a series of permanent bowlder embankments, terminating on their ends in masonry noses. On a minor channel a little lower down a permanent weir is constructed, close to the right bank, to prevent the Ganges from cutting too far in that direction; and a trifle below this, crossing a channel leading to the left bank, are the diverting weirs proper, consisting of a series of three temporary bowlder dams, built across the channel one behind the other in such a manner that the leakage through the first will be caught by the second and turned back into

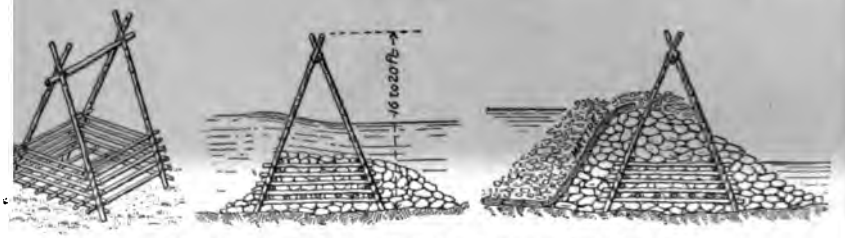


FIG. 16.—Details of temporary dams, Ganges canal heads.

the Hardwar channel, and that from the second will be caught by the third and diverted again to the Hardwar channel. These dams are destroyed each year by the floods and it has been found necessary entirely to rebuild them annually, new bowlders being brought down for the purpose, as the old ones are carried too far away to be economically collected. Experience has shown that this mode of construction of temporary weirs is less expensive than would be that of a permanent one at this place.

Large pyramidal-shaped cribs of timber are formed in the roughest manner and when placed in position are filled with bowlders (fig. 16). Bowlders are then thrown on top of these to strengthen and raise them higher and the channel face is covered with small branches and smaller bowlders and sometimes with earth to prevent excessive leakage. The velocity is about 10 feet per second in the major portion of the Hardwar channel, and its abrading effect is excessive, in consequence of which lines of temporary and of permanent bowlder banks and some masonry dams are carried from this point the entire distance along the sides of the channel to the main regulating weir below Hardwar. Just beneath and below the bowlder weirs above referred to masonry

bars are sunk in the bed of the side channel to prevent retrogression of levels, and a few hundred yards below and about opposite the city of Hardwar is a third channel leading from the Hardwar into the left channel. This is stopped by a permanent half-open masonry dam laid on a solid bed of masonry. In times of floods the sluice gates may be removed, while at low water their insertion closes the channel.

The regulating gates are at Myapur, at the head of the canal. Here are also the weir and scouring sluices proper. The latter works consist of a weir of solid masonry founded on the bowlder bed, with 15 scouring sluices, each 10 feet wide. The weir proper is only 525 feet in length, of which 200 feet are occupied by the scouring sluices and their piers. The sluiceways are deep and are closed by double sets of gates, some of which are raised and lowered by means of a traveling winch, the remainder being closed by simple planks or flashboards laid in the grooves.

SCOURING SLUICES.

The scouring sluices placed in open weirs consist of the foundation, the floorway, and the superstructure. The floor must be deep and well constructed and carried for a little distance above the weir and for a considerable distance below it. Above this are built up masonry piers at regular intervals, placed from 6 to 12 feet apart, and grooved for the reception of planks or needles, or closed with automatic gates or some other device which can be rapidly removed or replaced. By this means the water is kept under control and when low can be raised to the level of the crest of the weir by closing the gates, while in time of flood they are opened to secure a scouring of the river channel in front of the canal regulators. The masonry flooring is carried the entire width of the sluiceway, flush with the river bed and abuts well into the bank of the river. This is protected by a curtain wall of masonry up and down the stream.

The sluices in the weir at the head of the Lower Ganges canal at Narora are 38 in number, each 7 feet 10 inches in the clear. They have a total length of 427 feet, and the masonry piers separating them are but 2½ feet wide. The total length of these piers parallel to the course of the stream and at right angles to the line of the weir is 36 feet 4 inches, and they are practically two stories high, the upper deck or gallery having been constructed to have sufficient headroom to raise the gates (fig. 22). These gates are lifted by traveling winches running on rails on the upper deck. The sluiceways, like the main weir, are founded on a series of wells sunk in the sands and connected by brick masonry arches between which is a solid filling of brick (Pls. XI and XII). The total breadth of loose stones on the upstream approach to the sluiceways is 30 feet, and the total breadth of the bed of the sluiceways is 150 feet. Beyond this masonry flooring is carried and flooring of broken stone well packed for a distance of 100 feet

farther. The depth of the floor is 3 feet. The arrangement of sluiceway relative to the remainder of the weir and head-works is shown in Pl. XIII. The sluice gates are substantially constructed of wood and iron, and are two in number in each opening, the upper row when lowered abutting against the top of the lower row. In time of great floods both sets of gates may be entirely raised clear of the flood line.

The gates in the weir at Myapur, at the head of the Ganges canal, are similar to those described, and are represented in the accompanying illustration (fig. 17). The sluices in the weir at Okhla, at the head of the Agra canal, are similar in design to all others of this class, and contain 16 openings having a sluiceway of 138 feet. The openings, 6 feet wide by 10 high, are built into a masonry structure 19 feet high, and the gates slide between piers 2½ feet thick; they are raised by a

FIG. 17.—Myapur dam, Ganges canal.

traveling winch from above. The floor is founded on four lines of wells, and is 11 feet below the crest of the weir. The pavement of this floor is 8 feet wide upstream, 41 feet downstream, and 12 feet in the center of the weir. This is practically a single structure resting on the sand of the river bed, and is subject to considerable leakage. It is required not only to carry the weirs and their superstructure, but also to withstand the force of a torrent of water 16 feet deep.

Among the earliest and for that reason most interesting series of automatic sluiceways constructed are those in the Mahanadi weir, in lower Bengal, at the head of the Orissa canals. The sluiceway consists of 10 bays each 50 feet wide and separated by masonry piers. Each bay is closed by a double row of timber shutters fastened by wrought-iron bolts and hinges to a heavy beam of timber embedded

HEAD-WORKS, LOWER GANGES CANAL, NARORA.

in the masonry floor of the sluice.[a] There are seven upstream and seven downstream or rear shutters, the latter 9 feet high above the floor, and the former 7½ feet high.[b] During floods the upper row of shutters, which fall forward, are fastened down by clutches in an almost horizontal position, while the rear set, which fall backward or downstream, are kept in a horizontal position by the rush of water over them. In the dry season the rear shutters do duty by damming the water up, and for this purpose are provided with strong wrought-iron struts attached to their lower sides. In order to lift these the upstream set are first raised. This operation being aided by the press of water beneath, they are permitted to rise to a vertical position by means of a chain guyed to the floor above them. Relieved of the water pressure by this upper set of shutters it then becomes possible to raise the lower set, after which the upper set are lowered again into their original position, and the weir is in position to withstand a

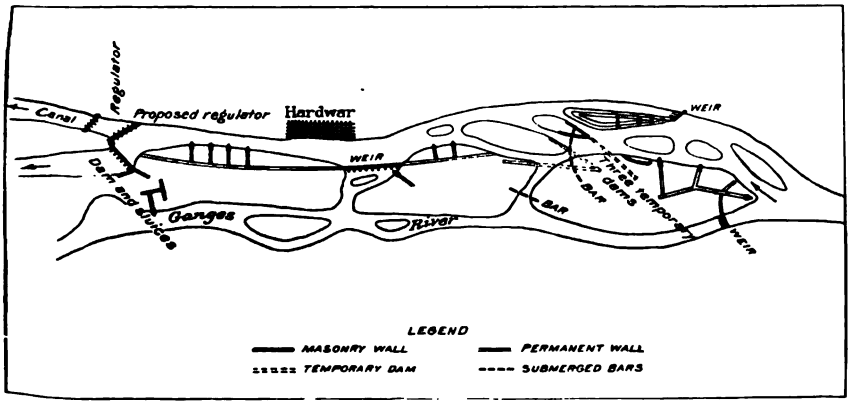


FIG. 18.—Head-works and weir training works, Ganges canal.

flood, as the lower set can be instantly dropped by merely removing the bolts which support them. The redamming of the water is accomplished in less than a minute. By reversing a lever each upper shutter is released, when they rise more or less rapidly, but with a comparatively slow motion until near the water surface, when they are brought home with a jerk, which does not seem, however, to cause a great strain.

Probably the best example of automatic or self-acting sluice gates are those constructed in the weir at Dehree, at the head of the Soane canals.[c] The sluiceways in this weir consist of three separate sets, one of which is placed close to the head of the main western canals, and are 537 feet 4 inches in length, containing 20 openings separated

[a] Roorkee Professional Papers, vol. 7, 1870, p. 75.

[b] Medley, Lieut. Col. J. G., Manual Thomason, College Civil Engineering, Irrigation Works, Roorkee, India, 1873, vol. 9, p. 118.

[c] Buckley, R. B., Fixed and movable weirs: Proc. Inst. C. E. London, 1879-80, vol. 60, p. 64. Medley, Lieut. Col. J. G., Manual Thomason, College Civil Engineering, Irrigation Works, Roorkee, India, 1873, vol. 9, p. 118.

by masonry piers. In the middle of the weir is another set of 16 openings 450 feet in length, and at the extreme eastern end of the weir, below the head of the main eastern canal, is another set of shiloways 337 feet 4 inches, with 20 openings. In addition to these shiloways there are, as in all Indian weirs, one or more fish ladders. In the Suane weir there are four separate fish ladders, one at the end of each of the shore shiloways and one on each side of the central sluice.

The crest of the weir is 3½ feet above the river bed. The gates by which the shiloways are closed are each 20 feet long and 9½ feet high. They are separated by masonry piers each 6½ feet wide and 32 feet long. As at first constructed these piers were much smaller, but it was found they would not withstand the jar produced by the manipulation of the gates and their thickness has since been increased. It is

FIG. 29.—Dropping the Suane automatic sluices.

estimated that the velocity of the current through these scouring sluices is about 17½ feet per second. The floor of the sluices is 90 feet wide, parallel to the river channel. As at first designed this flooring consisted of a substratum 4 feet thick of rubble paved with good stone 6 inches thick, but the difficulty of this construction was such that it was abandoned, and the foundations were finally set on blocks. These blocks are 10 by 6 feet, with two well openings each, and were built 3 feet high upon bamboo curbing laid on the surface of the sand, and when the brickwork had set they were sunk until their tops were a foot below water. Concrete was then thrown into the wellholes and around them, and when set in left a solid foundation for the masonry. The ashlar pavement on this solid floor is 15 inches thick in the bottom of the scouring sluices and 9 inches thick over the apron. Twenty-five feet upstream from the sluice flooring is a line of wells sunk 10 feet as a curtain wall to the apron, and the wellholes and interspaces are filled with concrete, as in the foundation of the flooring. The space between

:urtain wall and the sluice flooring is packed with large bowlders covered with pavement 9 inches thick. Twenty-five feet downam from the flooring of the sluices a line of wells has been sunk 10 and formed into a solid wall; the spaces between this wall and the ing have been tiled and packed with bowlders and stone, and downam from this point a talus, composed of large bowlders and blocks one, stretches 50 feet farther. The whole length of the sluice floorparallel to the river channel is 200 feet. Notwithstanding the workmanship of this foundation, the floods of 1874 proved very ructive, and tore away much of the river bed to a depth of 38 feet w the toe of the talus.

ie mode of construction and operation of the sluice-gates them-:s is as follows: These gates (fig. 25) are constructed of wood, well

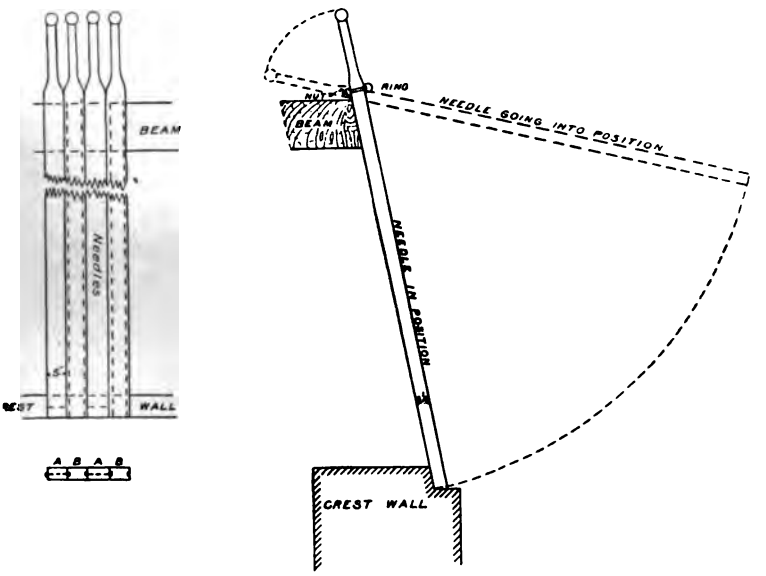


FIG. 20. Details of Sidhnai weir.

ed, and there are two for each opening. For each alternate pair ers on the downstream flooring a low masonry wall 1 foot high is out, which holds 1 foot in depth of water, thus forming a water ion on which the lower gate falls and relieving the piers of a porof the shock. The upper gate falls upstream, being hinged to the at its bottom, and abuts against a series of six struts, hollow iron ıders with small vent holes in which pistons work, so that when gate is raised by the water under it the impact against the struts lieved by the pistons plunging in the water in the cylinders. The ıstream gates fall downstream (fig. 19), and are supported by four rods hinged to their upper face below the center of gravity, and ı in position are held upright by chains attached to the piers. If gates are open and it is desired to close the lower one, so as to

cause it to dam the water up, the operation is performed in this man
The lower gate is first relieved by pushing aside the catch w
attaches it to the floor, and is raised a little by means of a hand le
whereupon the force of the water on the under surface brings i
slowly for a short distance, when it comes up with a jar agains
cylinder struts.

The pressure is now relieved from the lower gate, which is
raised by hand levers and chained in an upright position to the p
The upper gate is again lowered, now falling chiefly by its own w
through the water, and is fastened down. The lower gate, now
ing as a dam, is prepared to be released at a moment's notice.

The needles used on the Sidhnai weir (fig. 20) are an improve
on a very ordinary form of gate found in most of the simpler
older structures. At the heads of many old canals, and in some
ways, gates are found closed by two classes of needles, the sim
consisting of planks or flashboards let horizontally into grooves i
piers and raised or lowered, one at a time, until a sufficient nu
have been removed or introduced to regulate the discharge of w
The needle is formed by inserting these planks vertically bet
timber guides or abutments laid horizontally between the piers
water being regulated by the removal of as many as may be des
The needles employed on the Sidhnai weir are made of hard wo
such weight as to be manipulated by a strong man, each needle w
ing not over 40 pounds. They are 7½ feet by 5 inches by 3½ inc
size, with a stout handle 1½ feet long ending in a knob.[a]

The most difficult problem when these needles are in position
make the dam water-tight. Several methods were at first prop
Grooved needles were found to be unnecessary; ordinary need
the interstices between them were filled with wood shavings
chopped straw, were found to be readily made water-tight. Aft
needles are placed in position they are forced together by being d
horizontally with a crowbar, and a basket filled with shavings
is slipped down in front of the leak to be closed, the calking ma
being drawn by the current into the openings.

CANAL REGULATORS.

A set of regulating gates is always constructed at the head
canal. They must afford sufficient way to admit all the water the
is estimated to carry, and by them the amount admitted can b
trolled. Like the scouring sluices, these regulators consist of a
grooved piers resting on a foundation carried across the canal b

The water may be controlled by a set of planks or needles w
by hand in grooves, or, as is more usual, by drop gates raised an
ered by a winch from above. When not under too great a head
opening is closed by a single gate raised by a hand windlass or w

[a] d canal project: Selections of Records of the Government of India, No. 248, Calcu

me cases, under considerable pressure, a double series of gates, bove the other, is used, or else valve gates are employed, which orked by hand levers and screws from above. It is customary nnect the piers of the regulator by arches, so as to form a bridge s the canal, at the same time affording a convenient platform which to operate the gates. The bed and banks of the canal at ead are protected by masonry, so as to be safe from erosion when ates are opened.

locating the position of the regulating sluices, the principal t is to bring the water in the river through the scouring sluices ch a way that it shall pass directly in front of the regulator, pre- ing the deposit of silt at its head. This must be so established the canal will receive the desired volume of water with the least lity of receiving the heavy silt through the regulators or to dam- from matter carried by floods. Where this relation between ring sluices and regulators is such that the least eddy or quiet r exists between the two, there is certain to be a deposit of silt, h is an element of danger and must be removed. At the head of

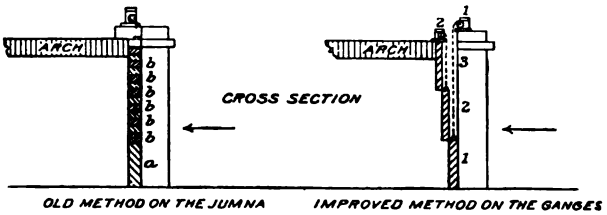


FIG. 21.—Regulating gates, Ganges and Jumna canals.

Ganges canal the location of the regulating gates is such that y deposits of silt are formed. At the head of the Soane canal face of the regulator is set back 30 feet from the abutment of the ring sluices, and here also is a heavy deposit of silt. At the Bari b head-works the regulating sluices are close to the scouring es and the current is so strong that small bowlders and gravel are ied through into the canal. The head-works of the Agra canal excellently located, and the river channel and canal line are so ly at right angles to each other that apparently no silting takes e. At the head-works of the Lower Ganges canal little or no silt- occurs, owing to the excellent relative location of the various eeways.

t Myapur, the head of the Ganges canal, the regulating bridge has ays or openings, each 20 feet wide and 16 feet high, fitted with s and apparatus for opening and closing. The breadth of the base latform on which the piers rest is 48 feet, exclusive of the cut- ers, which project upstream 4 feet. The roadway on top of the lge is 37 feet 9 inches wide between the rear parapet and the row windlasses on the upstream front. The shutter for closing the regu-

lators, while an improvement on that used on the Jumna ca
however, rather crude compared with the modern and im
methods employed on later constructions. The accompanying sk
(fig. 21) indicate the method of arranging the regulators on the
and on the Ganges canals. On the Jumna canal a regulat
drop gate are placed in a simple groove, and sleepers of scan
inches square are dropped in the top of the gate. This has
acted efficiently, but time and labor are required in its manipu
On the Jumna canals there is no great volume of water to c

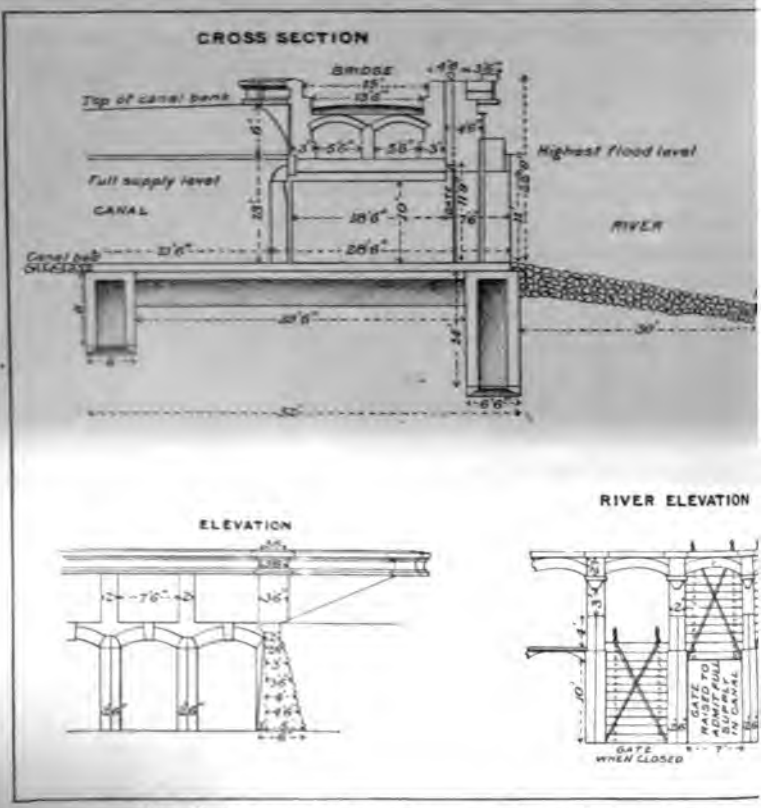


FIG. 22.—Narora weir, Lower Ganges canal; detail of canal sluices.

with, nor is there as large a number of bays as on the Gange
On the latter, as shown by the illustration, the bay is divid
series of gates, the most advanced one having its sill at t
canal bed, and two higher series of gates, each having th
ed 6 feet and retrograding toward the face of the bridge.
perated by separate windlasses over each. The two low
quite independent of each other, the third or upper ba
d by simple sleepers. The machinery attached to these
the simplest character and readily understood by the con
rer, while it is not liable to disarrangement.

om the plan of the relative locations of sluice-head (fig. 23) regulating bridge it will be seen that the triangle in front of the r affords an immense backwater or eddy in which deposits of silt t necessarily take place. Designs have recently been submitted , new regulating bridge which shall be a skew arch, the front face ntrance to the regulators being parallel to the channel of the ges and at right angles to the scouring sluices, the rear side being ght angles to the channel of the canal.

a interesting and unique set of regulating gates, because of the t pressure under which they are worked, are those at the head of Betwa canal (fig. 49, p. 177), and attention is called to them in this

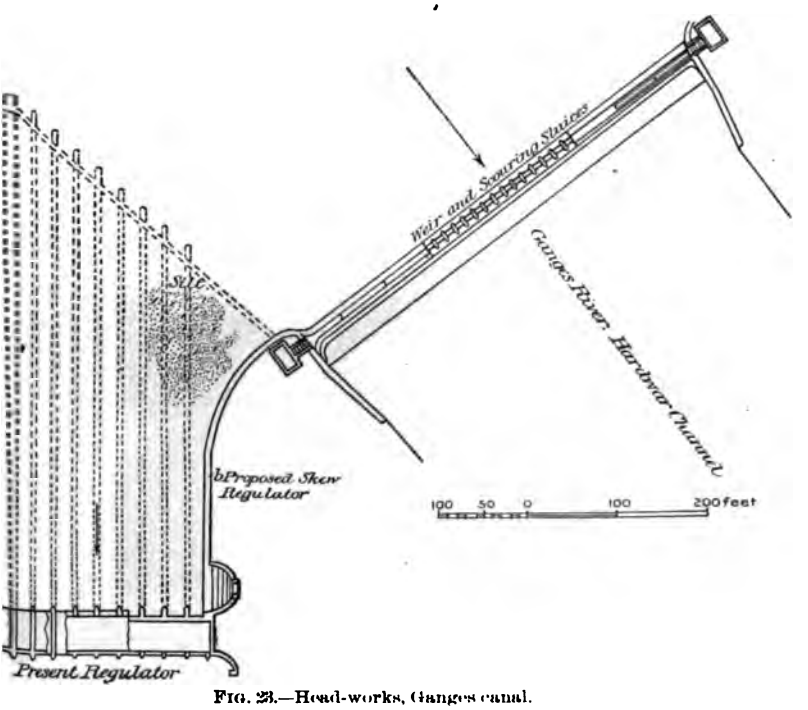


FIG. 23.—Head-works, Ganges canal.

e, though they will be more fully described later on. The regu- rs at the head of the Soane canal are placed at right angles to the ring sluices, though they are set back a short distance from the line he curtain wall leading to the scouring sluices. The floor of these lators is about 3 feet above that of the scouring sluices. The onry work in connection with the head-works of this canal is well structed, but perhaps too elaborate. These regulating sluices are gned to discharge 4,500 second-feet with a head of only 4 inches a depth of 9 feet of water. They consist of 24 openings, each 6 wide, and separated by the solid piers which support the bridge ve. There are two shutters constructed of wood, opening verti-

cally (fig. 24). Usually only the upper gate is used, the chief of silt thus taking place in front of the lower gate, where it dredged out, but when the head of water is very low the lowe sometimes raised. The silt is thus flushed out and deposite canal, where it is still more easily dredged. These shutters ar by a traveling winch supported on a hand car on rails on the above. The figure shows the mode of raising these gates fastening them together when both are to be opened.

At Vir, where the head-works of the Nira canal are situat regulating gates are simple, giving a water way through sev arate bays, each 4 feet wide, and operated from a masonry above (fig. 45, p. 170). These are so designed that under the available head of 9 inches the full discharge required will be ad to the canal.

The regulators at the head of the Lower Ganges canal, like t and scouring sluices (Pl. XIII and fig. 22), are founded on tw

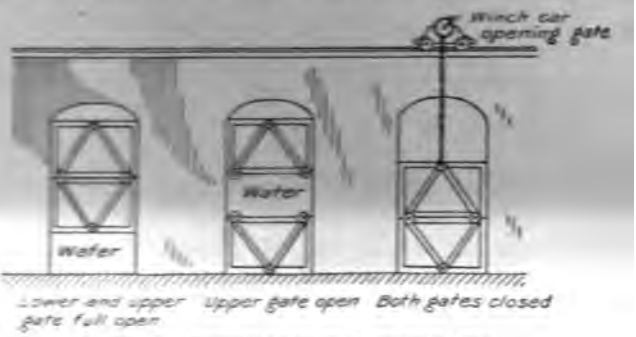


FIG. 24.—Regulating gates, Soane canal head.

of wells. Curtain walls founded on wells are carried along th of the river and canal for a short distance. The flooring of t lators is well paved with substantial masonry from 3 to 5 fee and a rough loose-stone pavement is carried for some distar the river above the regulators and 100 feet below them, the b the canal being revetted for some distance farther. The widt canal head is a little greater than that of the canal, caus velocity for a short distance to be diminished, in consequence the majority of the silt is deposited at this one place, where i most conveniently removed. The total width of the regulato head is 282½ feet. There are 30 bays, each 7 feet wide, separ substantial masonry piers 28½ feet long by 2½ feet wide. T closing the entrance to the canal head are of iron and slide ve They are each 11 feet high, are raised by a winch traveling bridge overhead, and are closed by their own weight. In the the upstream side of these gates are grooves in which planks inserted in order to reduce the head on the gates when o them.

ıe regulator at the head of the Sidhnai canal consists of four 60° es of 22.5 feet span, with jack piers 2.5 feet thick in the center, ɜh divide the waterway into eight spans of 10 feet each. The arches

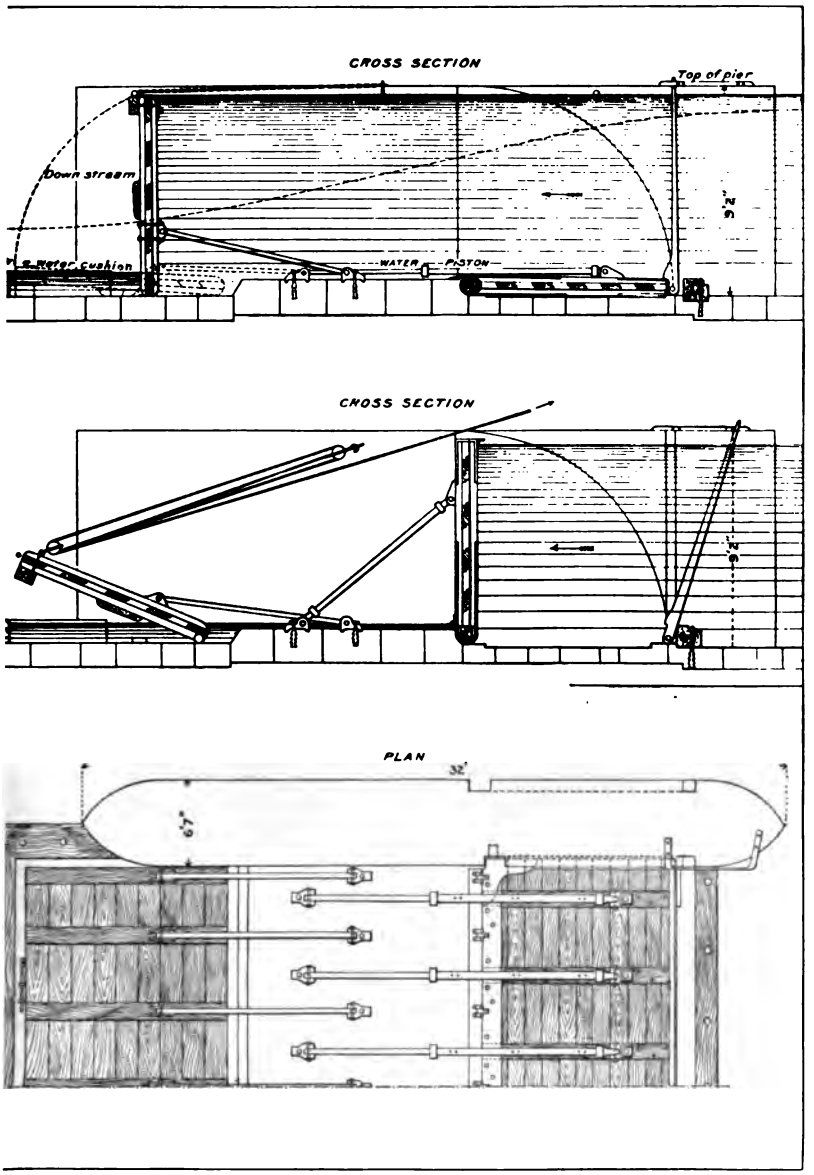


FIG. 25. - Soane canal, automatic sluice gate.

ng from 6 feet above the floor. The floor is 1 foot above the crest he weir, and as the needles on the top of the latter are designed to l up 7½ feet of water, 6½ feet can be forced into the canal. There

is nothing novel in this regulator, the gates being made of wood bound with iron and sliding in cast-iron grooves. The lifting apparatus is a traveling winch working on rails on the top of the parapet of the bridge, so placed that the drum of the crab winch is centrally located over the gate to be lifted. There is an upstream set of grooves in the piers into which planks can be inserted to relieve the gate from pressure should it jam. Planks are generally used for regulating the supply in the canal, the gates being intended for use only when it is necessary to close the regulator quickly.

WELL FOUNDATIONS.

Wells and blocks may be considered as one and the same form of construction, though perhaps blocks are more properly rectangular wells having one or more well holes in them, while wells proper are circular in plan with a single central opening. They are in reality brick caissons from 6 to 20 feet in diameter, the walls varying in thickness from 2 to 4 feet and of any required height. Blocks are rectangular brick caissons, perhaps 6 by 10 or 12 feet, with 2-foot or 3-foot walls, and subdivided into two or even four vertical passages or well holes. For the piers of the Solani aqueduct the blocks are 20 feet square and divided into four well holes. At the head of the Agra canal they are rectangular, 13½ by 9 feet, and contain two well holes, each 4 by 3 feet. At the head of the Lower Ganges canal they are round, 12 feet in diameter, with walls 2 feet thick.

In sinking wells the water in the part of the river to be operated upon is usually temporarily dammed and the earth removed until the water surface is again reached. Curbing of bamboo of the size of the well is then laid, and on this the well is built up. It is commenced by placing on its lower edge a cutting surface of wood or iron, wedge shaped, with the cutting point downward. Into the top of this the masonry work is built. As the building continues the sand and gravel are removed from within by hand or by dredge, and the well sinks by its own weight. Much difficulty is frequently encountered in sinking these wells, owing to their uneven subsidence or on account of meeting layers of earth of different character, which must be removed or the well so loaded as to cause it to sink vertically. When the well or block is sunk to the required depth it is usually filled with concrete, and thus becomes a solid pillar. The spaces between the walls are then protected by sheet piling, and after the removal of the sand concrete is placed between them, thus forming a continuous wall. This method is simple and not costly. It is particularly effective in deep sand or in quicksand, and may be carried on by workmen with little risk of danger.

The depths to which wells are sunk differ greatly. In the case of the head-works of the Agra canal no wells whatever were made under the weir, as it rested directly on the sand. At the head of the Soane

SINKING FOUNDATION WELLS, NADRAI AQUEDUCT, LOWER GANGES CANAL.

al the wells are sunk about 10 feet below the base of the weir; and Narora, at the head of the Lower Ganges canal, they were sunk 20 ;. Wells are built either in single or double rows, the distance ween these varying according to the dimensions of the wells them-ves. They have in some cases been connected by brick masonry hes, and the interspace below the arch filled with solid brick. This ı done in portions of the head-works of the Lower Ganges canal. 'he most striking case of the construction of wells as a foundation a masonry superstructure is that of the wells for the support of Nadrai aqueduct on the Lower Ganges canal over the Kali Nadi 'rent. The whole structure of the aqueduct, including river and al wing walls, is founded on wells, the cutting edges of which are ık 51½ feet below the level of the Kali Nadi Torrent at that point, average depth of the wells being 56 feet. The wells are of three ss, being 20 feet in diameter for the piers and canal land wings, 13 t in diameter for the river piers, and 12 feet for the abutments. ere are 102 wells 20 feet in diameter, 44 wells 13 feet in diameter, l 122 wells 12 feet in diameter, or a total of 268 wells on this work. e total linear depth of well sinking amounted to 15,008 feet. Accom-nying are given illustrations showing some of the details of these lls (Pl. XIV).

The well curbs were generally constructed of wood, with wrought-n bolts 1¼ inches in diameter projecting from them and built up o the brickwork. In the 12- and 13-foot wells only one dredger was rked at a time, and the average rate of sinking was 1 foot per day. the 20-foot wells three or four dredgers could be used at once, and th this number the rate of sinking amounted to 1¾ feet per day. ilding and sinking went on alternately in the construction, the ickwork being carried up in lengths of about 8 feet, as the wells ık that much. When 25 feet had been sunk the brickwork was rried up the full height, 47½ feet above the cutting edge, and the ıking continued until clay was reached. On a well showing even ı slightest signs of going out of the perpendicular dredges were rked on the opposite side from that to which the well inclined. In treme cases a "jham" was worked from a windlass on top, which rred up the silt in the sump less than did the dredger and allowed leeper hole to be made on one side. Only two or three of the 20-ot wells were 1 in 40, and the majority less than 1 in 100 out of rpendicular when the under dredging was stopped. In the lines of ı abutments, where the 12-foot double rows of wells were only 2 feet art, there was a decided tendency for each pair of wells to lean toward ch other and for the curbs to separate. In some cases where the lls got out of perpendicular or failed to sink in the hard clay, it came necessary to load them with railway iron or a temporary perstructure of brick. To test their resistance against subsidence ne of the less satisfactory wells, after they had been hearted with

concrete, were loaded with a great temporary superstructure of bricks, which in the case of one well weighed 1,451 tons (Pl. XIV). The total subsidence amounted to but 1¼ inches. After the well had gone through the blue clay and while dredging in the brown sand was in progress, inblows of the blue sand above the clay were of frequent occurrence. These were generally caused by the dredger being worked awkwardly. Sometimes the inblows were so rapid as to bury the dredger before it could be lifted, and at other times they were extremely gradual. These inblows frequently caused the well to incline from the vertical. When it was found that some of the 12-foot wells inclined from the vertical, advantage was taken of it to make them incline, so that when finally loaded with the superstructure and arch they would be in the best position to receive the arch thrust.

Mr. Beresford, the superintending engineer, in a note on "Frictional resistance to sinking due to lateral pressure of earth on the sides of a well,"[a] shows that the pressure Py exerted by earth against a vertical plane per unit of the breadth is

$$Py=\frac{Wx^2}{2}\cdot\frac{1-\sin O}{1+\sin O},$$

where W=the weight of earth per cubic foot, x=the depth the plane is sunk below the surface of the earth, and O=the angle of repose of earth. The values found practially agree very closely with those derived from this formula. From some computations it was found that the value of $Py=\frac{100}{2}\times 58^2\times 0.33\times 63=3{,}496{,}878$ pounds=1,562 tons, taking W=100 pounds; O=30° and the coefficient of friction of the masonry on moist clay as given by Rankine=0.33. Therefore the friction F=1,562×0.33=515 tons.

ESCAPES.

In order to establish a complete control over the water in a canal channel, provision is made for disposing of any excess which may arise from sudden rains or floods, or from water not being required for irrigation. This is effected by means of escapes or short cuts from the canal to the river or other natural waterway into which the excess of the water can be discharged. These escapes perform the additional service, in the case of streams carrying much sediment in suspension, of flushing the canal, thus preventing or removing excessive silt deposits. Colonel Cautley, in speaking of escapes and their employment on the lines of distributaries, says:

> In times of flood, opening the heads of the distributaries relieves the main canals, and the former are in turn relieved by the escapes. Hence the distributary heads become the safety valves, and the escapes the waste pipes of the entire canal system.

[a] Gordon, W. B., Notes on Well Sinking, Nadrai Aqueduct, Public Works Department, North-west Provinces, India, p. 20.

Escapes are provided at certain intervals along the entire canal line, and a double set of regulators are made at the point where the escape is taken off, as in the case of a branch canal or distributary. On the Ganges canal they are projected at every 40 miles, though much depends on the convenience with which they can be made and the proximity of the canal to some water course into which the escape water can be conducted. They are also provided if possible at dangerous points, as above or along lines of heavy embankment where, in case of the bursting of the bank, much damage would ensue. The first main escape is always constructed at a distance of half a mile or less below the canal head, and when it becomes desirable to scour out the silt accumulated between the head and the escape the latter is opened and a large volume of water admitted to the canal. This runs off through the escape carrying the silt with it. It is usual in such cases to decrease the slope of the canal for a short distance below its head to cause the deposit of matter carried in suspension between that point and the escape.

The escape cut must be sufficiently large and have enough fall to carry off the whole body of water which can reach it, so that if necessary the canal below the escape may be left dry for repairs without stopping its running above. The complete control of the canal waters by double escapes consists of the construction of a regulator at the head of the escape, and another one across the canal channel immediately below the escape. These escape heads are similar to the regulating bridges previously described and to the various regulators constructed at the heads of distributaries. When a heavy rain occurs on the line of a canal the irrigators cease to use the canal water, and as the flow can not be immediately stopped at the head-works, great damage would be done by the surplus water but for the escapes, which act as though the head regulator of the canal had been brought so much nearer the point of application.

The Khutowli escape head on the Ganges canal is an interesting example. It is at the sixty-second mile and consists of a channel excavated 60 feet wide and 3½ miles long. The masonry head consists of ten openings, each 6 feet wide, the height from the flooring to the soffit of the arch being 8½ feet. The flooring is 64 feet wide, 40 feet of which forms the tail, and is laid on a slope of 1 foot from the level of the canal bed. The banks of the works are protected by masonry revetments and guards of piling and rubble which protect the floor from the wear and tear of the current.

Colonel Cautley made the following rules to control the location and regulation of escapes on the Ganges canal:

With reference to position, the distance between the escapes is limited to 40 miles, considering that by adapting their capacity to the volume of water contained in this length of canal the facilities for regulation are ample. In the sandy tracts of the canal the number of the escapes is multiplied rather than having their waterway increased. The sites of all escapes are fixed in such a position that the

water may be plunged into the bed of the receiving channel and that the high-water mark of the latter shall never interfere with the free discharge of the canal. The escape channel shall, when perfected, have, in addition to the initial slope of 12 inches from the bed of the main channel which is given to the tail of the escape head, a slope of bed equal to 1½ feet per mile.

FALLS AND RAPIDS.

As the natural fall of the country through which a canal runs is usually greater than the slope of the canal, it becomes necessary to compensate for this difference of slope. This is done by concentrating it at a few points where vertical falls or rapids are introduced.

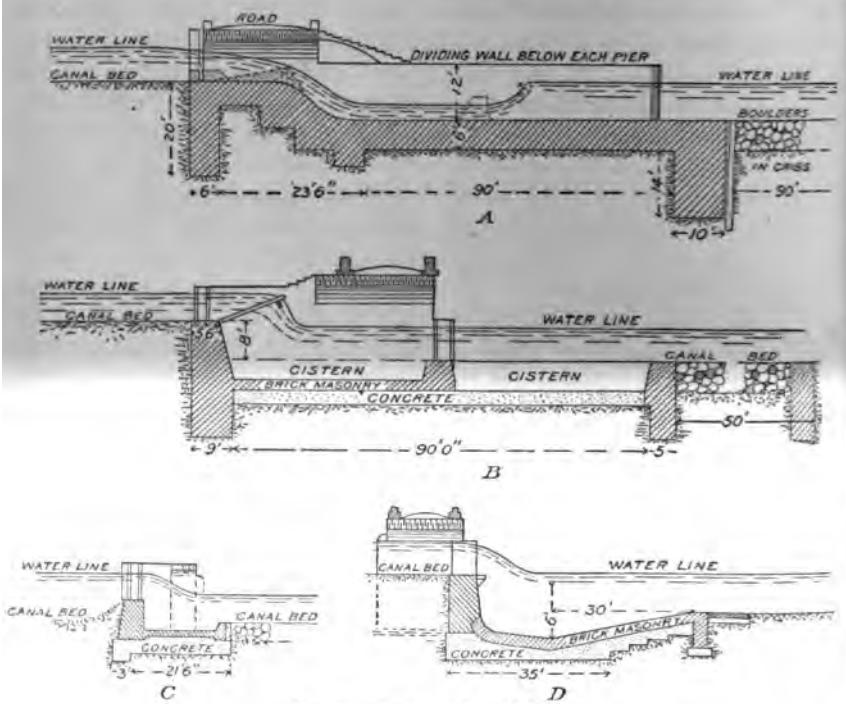


FIG. 26.—Sections of canal falls.

The location of these is usually fixed by the place where the canal becomes too high above the surface of the ground, while their exact position is made to coincide if possible with that of a bridge or similar work in order to economize masonry construction.

Ogee falls were first adopted on the Ganges canal and are of the shape shown in the accompanying figure, the intention being to break the force of the fall of the water. They were about 8 feet high, but the shock of the fall proved so great that they have been modified to give two vertical falls, the lower of which drops into a water cushion. On the Ganges canal were a number of ogee falls (fig. 26, *A*) 15 feet high. These have been so remodeled as to give an upper fall of 5 feet, then

ASAFNAGAR FALLS, GANGES CANAL.

ıort level bench of 10 feet, and a vertical drop of 10 feet, ending a shallow water cushion (Pl. XV). These falls have a solid sonry floor 4 feet thick. On some falls the action of the water is ɜened by making it play over a wooden grating. This reduces the ɔck by dividing the stream into a number of fine threads. Falls invariably constructed of substantial masonry laid on a deep and n foundation. The banks are protected by masonry and paving. e latter is carried for some distance below the fall both in the bed l on the sides, and the flooring terminates in a row of sheet piling. broad canals like the Ganges the fall is generally divided into com- :tments by longitudinal dividing walls, so that when repairs are ɜessary one portion may be laid bare at a time. On the Ganges ıal most of the falls are constructed at points where bridges would necessary, and to the lower side of the bridge the fall is attached. low this the channel of the canal is widened out, the flooring and es to the extremity of the cistern in which the fall terminates being efully and securely paved and revetted.

Experience seems to show that vertical falls with gratings, as used the Bari Doab canal, and terminating in water cushions, are the t that have been devised (fig. 28). The grating consists of a num- of wooden bars, resting on an iron shoe built into the crest of the , and on one or more crossbeams, according to the length of the bars. ɜse bars are laid at a slope of 1 on 3, and are of such a length that full supply water level in the canal is half a foot below their upper s. The dimensions of the bars used where the depth of the water ½ feet are as follows: Lower end one-half inch broad by three- rths of an inch deep; upper end one-fourth inch by three-fourths ı deep. They are supported on beams 1 foot broad by 1 foot deep. first these beams were 6 inches apart, but it has since been found t to increase this distance a trifle, and now 18 bars are placed in a oot bay. The bars are undercut from the points where they leave shoe at the crest of the falls in such a manner as to make each ce an orifice in a thin plate.

The effect of a fall at the end of a canal reach is to increase the ɔcity and to diminish the depth for some distance above the fall. s increase of velocity produces a dangerous scouring on the bed banks of the canal, and is guarded against by heading the water at the crest of the fall by means of sleepers dropped in grooves of piers, thus increasing the height of the fall. The narrowing of canal banks at the fall produces the same effect. The better ;hod, however, is to raise the crest of the fall by a masonry weir, the height necessary to raise it is found by the following calcula- ı, given by Colonel Dyas:

$$H=\left(\frac{900\,a^2\,d}{l^2\,s}\right)^{\frac{1}{3}}-125.8122\frac{d}{s}$$

vhich H is equal to the height of the water above the crest of the

fall; a is equal to the sectional area of the open channel; d equals the hydraulic mean depth of the same; l is equal to the length of crest of the fall, and s equals the length of slope to a fall of one in same. When gratings are used these act instead of a weir in checking the velocity of the water, and the method of spacing them is such that the velocity of no one thread of the stream shall be either increased or retarded by the proximity of the fall.

On the Soane canal, where there are many locks, the falls are nearly always introduced at the points where the locks occur (fig. 27). The main line is carried through the locks, and the waste weir or branch channel is carried around them, and in it the surplus water over that which is required for the operation of the lock is conducted. In this branch channel a fall must be constructed. In one case noticed, where there were two locks, with a total lift of 20 feet, the fall was constructed

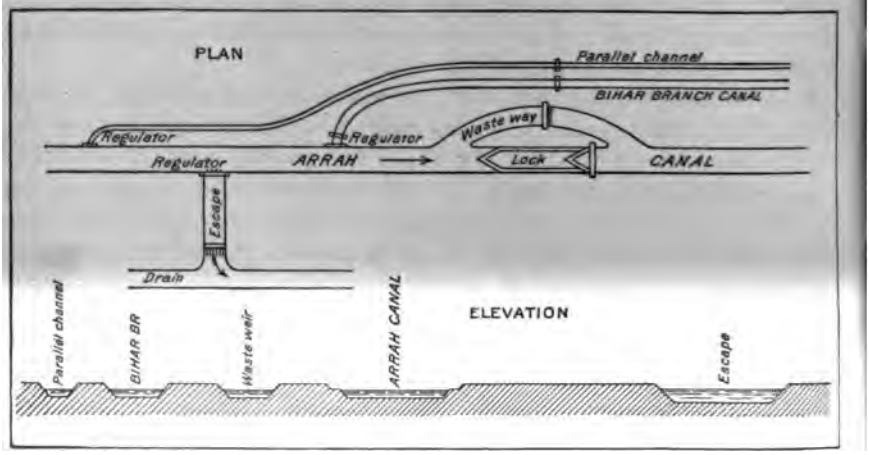


FIG. 27.—Soane canals, Bengal: arrangement of branches and escape at Dunwar.

in three bays. The channel was 40 feet wide and the falls were built of substantial brick masonry terminating in a deep cushion below. On the Agra canal are several interesting falls, perhaps the most elaborate of which is the Kushuk fall, on the Bata escape (fig. 30). This is a masonry fall, or rather two falls terminating in water cushions, the total height of which is 27 feet. The total length of the masonry work is 190 feet, and the depth of the concrete flooring is 3 feet, terminating on a well, on which the toe of the apron rests.

Instead of falls, rapids have been constructed with great success on the Bari Doab canal (fig. 28). The slope of the rapid is paved with loose bowlders, confined by walls of masonry built at intervals of 40 feet longitudinally across the stream. From experience on these rapids it has been found that dry bowlder or rockwork is not to be depended on for velocities over 15 feet per second, and that over this the slope must be modified or masonry be used. On the Bari Doab canal rapids were adopted wherever bowlders were procurable at moderate expense.

Bowlders form the best material for the flooring of a rapid. Brickwork should not be used with currents of high velocity, as the best bricks do not stand the wear and tear for any time, certainly not for service in contact with velocities exceeding 10 feet per second. The bowlders were generally grouted in a good bed work of mortar and small pebbles or shingle, where velocities above 15 feet per second were employed. The tail walls on these rapids are of peculiar construction, for the purpose of turning back the eddies and of protecting the canal banks from the direct action of the water. Beyond a point where the heaviest action occurs and where the greatest width is given the tail-works, the banks incline toward each other so as to direct the set of the stream to the middle of the canal. The tail walls are not kept to their full height throughout, but gradually become lower and lower, till they disappear altogether, where they reach the same level as the bed of the canal. In case no tail works are given, the banks are faced with bowlders or piling for a length of perhaps 300 feet below the rapid. On distributaries and their branches falls and rapids are resorted to, as on the main canals, differing only in details of design.

DRAINAGE WORKS.

In canals where the diversion line is carried along the sides of hills or slopes, great difficulties are sometimes encountered in passing the side drainage which crosses the canal lines. Much can be done by diverting water courses or constructing short drainage cuts emptying into natural drainage lines. When the drainage can not be diverted it may be passed in one of several ways. If the stream is at a lower level than the canal the latter may be passed over it in an aqueduct, which in most cases will involve the construction of some embankments before the stream channel proper is reached. If the canal and stream meet at the same level the latter may under exceptional circumstances be permitted to enter the canal. This will necessitate the introduction of proper regulating works below the canal crossing, and an escape or dam on the opposite side to the inlet. In the case of very small streams entering a canal at level, an inlet only is necessary, the surplus water being passed off through the first escape in the canal channel. If the stream encountered is at a higher level than the canal it is generally carried over the latter in an aqueduct, which is called a superpassage. In the case of nonnavigable canals, less elaborate drainage methods than those described may be employed, and modifications of these methods are used, as when the canal is carried under the stream in an inverted siphon, or a combined siphon-aqueduct has been constructed.

By means of simple diversion of the course of a stream much expense may be saved. An instructive example of diversion is that of the Chuki Torrent on the Bari Doab canal. At the time of the construction of the canal this torrent had two outlets. Just above the

crossing of the canal the main channel divided, one channel ru into the Beas and the other into the Ravi River. The latte embanked close to the bifurcation by bowlder dams and spur tected by masonry revetments. By this means the whole of the was forced to flow into the Beas, and the expense of the work of ing the canal was saved. Another instance is that at the head Betwa canal. The first 6 miles of this is protected by a dra channel 15 feet wide at the bottom and 6 feet deep, which parallel to the canal and carries the drainage into a small st whence it is let into the Betwa River. At the Betwa head-wo creek enters the river, and this was blocked up by a large embank and turned back by a cut, through which it entered the river a the head-works.

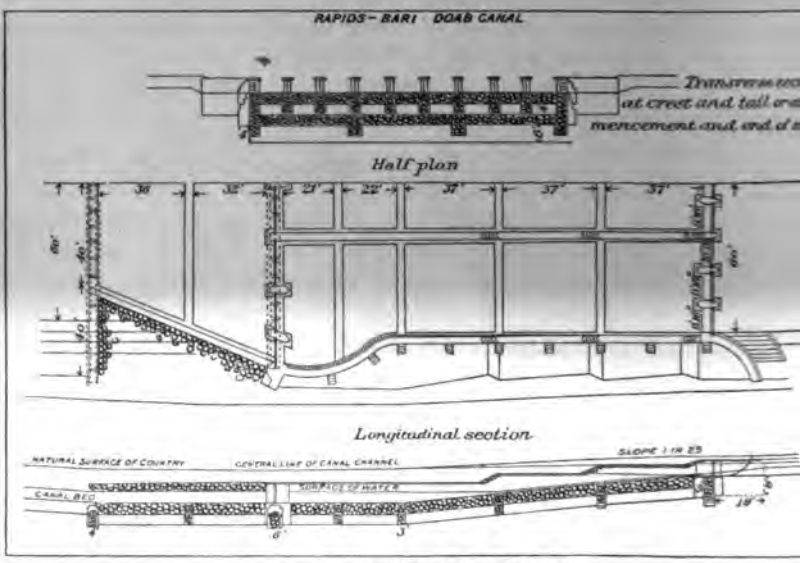


FIG. 28.—Rapids, Bari Doab canal.

Aqueducts differ from bridges only in having to carry a water c nel instead of a railroad or roadway. The bridge portion may wood, iron, or masonry. In India, masonry is almost exclus employed because of its relative cheapness and permanency. O Soane canal are several interesting aqueducts, one of which, a the Thora Nulla, carries the Buxar branch canal on a well-constru masonry structure (fig. 8, p. 102). This aqueduct is 38½ feet in h and, exclusive of the wings or retaining walls, is 155 feet long width exclusive of wings being 54 feet. The waterway of the aque is 42 feet wide on top, 40 feet at the bottom, and 7 feet in depth. waterway for the torrent beneath the aqueduct is constructed al as an inverted siphon, the bed having an inverted arch beneat piers. There are four spans, each 30 feet wide by 20 feet 9 in

SOLANI AQUEDUCT, GANGES CANAL.

high, the arch above supporting the aqueduct. The height of the piers to the springing of the arch is 12 feet and the rise of the arch is 6 feet. The piers are each 6½ feet wide. The object of the invert is, that should a greater flood occur than is estimated for, the openings may act as siphons. They are estimated to carry 10,000 second-feet.

One of the greatest and earliest aqueducts constructed is the Solani aqueduct on the Ganges canal at Roorkee (Pl. XVI). This consists of an earth enbankment 2¾ miles in length across the Solani Valley, and about 16½ feet high, its greatest elevation above the river bed being 24 feet. This embankment, as shown in the sketch (fig. 29), is 350 feet wide at the base and 290 feet wide on top, and on this the canal banks are formed. The outer edges of these banks are 30 feet wide and 12 feet deep, and are lined throughout by masonry or revetments of stone. The exterior slopes of the embankment are 1 on 1½, and have been made with great care. The total length of the upstream revetted channel is 10,713 feet; that of the downstream channel is 2,723 feet, and between these embankments is built the masonry aqueduct, the total length of which is 920 feet, with a clear water

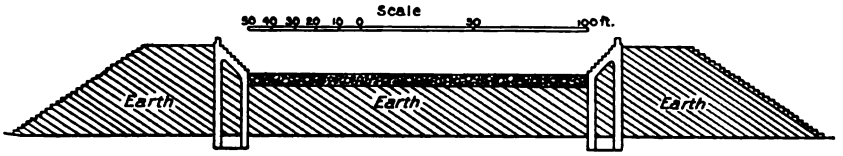


FIG. 29.—Cross section of Solani aqueduct, Ganges canal.

space between piers of 750 feet in length, consisting of fifteen spans of 50 feet each. The breadth of each arch parallel to the channel of the river is 192 feet and its thickness is 5 feet. The arch is in the form of a segment of a circle with a rise of 8 feet, and the piers are raised on foundation blocks of masonry, sunk 20 feet in the river bed. The greatest height of the aqueduct proper above the river valley is 38 feet. The waterway of the aqueduct is formed in two separate channels, each 85 feet wide; the outer walls of masonry are 8 feet thick and 12 feet deep, the aqueduct being intended to carry 12 feet of water. The velocity through the aqueduct is 3⅔ feet per second.

Perhaps the most magnificent aqueduct yet constructed is that built across the Kali Nadi at Nadrai, which carries the waters of the Lower Ganges canal over that river. The first aqueduct at this place was much smaller than the present one. Before the great flood of 1885 it was calculated to permit the passage of 30,000 second-feet through the five bays into which this water way was divided, and it was founded on the natural channel of the torrent. In 1884 an extraordinary flood occurred which discharged nearly 100,000 second-feet under the aqueduct, and greatly injured it. Repairs were at once commenced and slight alterations made in order to increase the channel. On the 2d of

October, 1884, a flood level was noted on the upstream side corresponding to a reading of [illegible] feet on the downstream gage, the difference of surface level above and below the aqueduct being 3¼ feet. The mean velocity of discharge in this flood was about 10¼ feet per second. This work had scarcely been commenced when, on the 17th of July, 1885, another and greater flood occurred. This flood is fully described in notes made at the time by the executive engineer, Mr. W. Good:

Early on the morning of the 17th the river began to rise and the water level rose in a wave 4 feet high and carried away part of the revetment. Other waves 10 or 15 feet high surged over it, and the whole of this revetment work and the abutments collapsed. Shortly afterwards the piers were carried away and parts of the aqueduct fell into the stream. The velocity was terrific. The water in the main stream was piled up in waves 20 feet high at intervals of 100 feet apart. By 2 in the afternoon 100 yards of the canal bank had been carried away and all of the aqueduct had been destroyed. From 4 o'clock in the morning to 3 o'clock in the afternoon the level of the water rose to a total height of 23 feet and had a velocity of over 18 feet per second. From estimates made by Mr. Good the discharge of that flood was probably 133,000 second-feet, and during the rain storm (which lasted three days), an average of 22 inches of rain fell on the whole catchment area. The greatest fall occurring in one day, the 16th, was 9 inches on some portions of the basin.

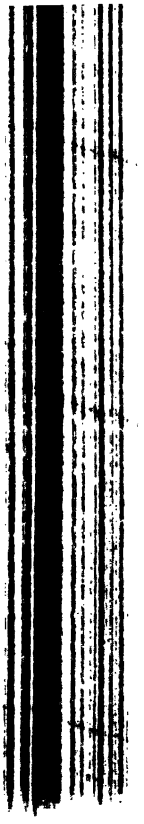
In estimating for an aqueduct to replace the old one, this flood was considered as the greatest which was ever likely to occur, and the new aqueduct as now finished is estimated to discharge under it 140,000 second-feet, with a velocity of 8 feet per second, thus requiring a waterway of [illegible] square feet. This is equivalent to a run-off of [illegible] per square mile of catchment, the total area of which is [illegible] square miles. The waterway for the canal on top of this aqueduct [illegible] carry [illegible] second-feet.

[illegible] consists of 15 masonry spans, each 50 feet [illegible] wells. The maximum pressure on the foundation [illegible] exceed 2½ tons per square foot. Under the aqueduct is [illegible] concrete floor 5 feet in thickness. The total cost of this work was about $1,525,000.

On the [illegible] canal are two of the largest as well as the most interesting superpassages constructed in India, one for carrying the Puth Torrent and the other the Ranipur Torrent over the canal. In the construction of a superpassage especial care must be taken to give its bed such a slope that it shall not be filled up by the deposit of sediment while the masonry and revetting of the banks must be carried a sufficient distance on each side of the canal up and down stream to protect the foundations of the work.

[illegible] of the Kali Nadi aqueduct: Records of the Government of India, Public Works Department, Calcutta, 1888.

RANIPUR SUPERPASSAGE, GANGES CANAL.



The catchment basin of the Ranipur Torrent is about 45 square miles, average width being 4½ miles and its total length 10 miles. At the nt where the superpassage is constructed there is an ogee fall with rop of 9 feet, the base between the piers supporting the superpas-ge being used as a portion of the masonry construction of the fall . . XVII). The foundations of the upper and lower levels are pro-ted by lines of piling and box work; the former have a width of 10 t and the latter of 70 feet. The flooring of the superpassage from crown of the arches to its bed is in its thinnest place 3 feet thick, the parapets are 7 feet wide and 4 feet high. These continue and from the body of the work a distance of 100 feet on each side, anding outward so as to form wings for keeping the water within unds. This superpassage is 300 feet long and provides a waterway the torrent 195 feet wide and 6 feet deep.

At the Puthri superpassage the torrent of that name drains an area about 85 square miles and discharges a maximum flood of 15,000 cond-feet. This superpassage consists of an aqueduct, under which canal passes in nine bays, each 25 feet wide. The width of the perpassage is 296 feet. This waterway, as it now appears, was made wide, and accordingly the decrease in the velocity of the torrent this point, which in the natural channel is 16 feet per second, has used considerable silting and the superpassage has been constantly ling up. This error has been obviated by decreasing the waterway the construction of masonry groins projecting from the side para-ts of the superpassage out into the stream at right angles to its urse. This has nearly remedied the evil, as the silt previously posited is now being rapidly cut away.

The Sasoon superpassage (fig. 36) on the Sirhind canal, whereby e Sasoon Torrent is carried over the canal, drains an area of 24 uare miles. The discharge of this stream is estimated at 7,750 cond-feet, and a waterway has been provided 150 feet wide by 6½ et deep. The difference in level between the bed of the canal and e torrent is 21.9 feet, of which 7 feet are depth of water in the nal, 10 feet headway up to soffit of arch, 3 feet the thickness of the ch, and 1.9 feet brick flooring. The canal channel is spanned by ree central arches, each of 45 feet span, and two at the sides, each 32 feet span. There is an aggregate waterway for the canal of 184 et, but the mean waterway of the channel is only 177 feet. The le walls or parapets of the superpassage are 10 feet high and 5 feet ick at base. The mode of construction of this superpassage is indi-ted in fig. 36, p. 149.

An interesting mode of disposing of drainage is by a drainage servoir, as is done on the Agra canal. Several streams cross the nal at a certain point. They are, however, all disposed of through e channel by constructing an embankment on the upper side of the nal, so that a reservoir is made. The object of this reservoir is not

[illegible] The embankment is of earth and [illegible] feet high. The bottom or sill of the superpassage, which carries [illegible] flood water over the canal, is [illegible] feet above the bottom of the [illegible] voir, the object being that the [illegible] 20 feet of the bed of the reservoir [illegible] be cultivated and supplied from [illegible] water. A large revenue is [illegible] to the government from the lands [illegible] tivated in the reservoir bed after [illegible] waters have been drawn down thr[illegible] the superpassage. This superpas[illegible] is constructed of boiler iron. It [illegible] feet long, 30 feet wide, 10 feet [illegible] cross braced by angle iron on top, [illegible] supported by two piers each 5 [illegible] thick. It is well built and suppo[illegible] and the slope is steep, giving a [illegible] velocity to the water. The con[illegible] tion between the ends of the su[illegible] passage and the abutments is [illegible] of heavy sheet lead, to accommo[illegible] the changes due to expansion of [illegible] iron and to prevent leakage. A[illegible] flowing through this superpassage [illegible] water falls vertically 12 feet, and [illegible] 25 feet into the old channel of [illegible] River Jumna.

FIG. 31.—Agra canal, cross section of Rutmoo Falls.

The Rutmoo Torrent is pa[illegible] across the Ganges canal by a [illegible] crossing (Pl. XVIII). This consis[illegible] a simple inlet at the torrent entr[illegible] to the canal and of a masonry o[illegible] dam and escape regulator in the c[illegible] bank opposite the torrent inlet, w[illegible] there is another regulating br[illegible] across the channel just below [illegible] inlet (fig. 31). By this means [illegible] flow of water is easily regulated, [illegible] amount admitted to the canal b[illegible] the inlet being controlled by the r[illegible] lator in the canal itself and the su[illegible] fluous water being discharged thro[illegible] the regulating breach or dam in [illegible] canal bank. This dam consist [illegible] 47 sluice ways, each 10 feet wide, with their sills flush with the c[illegible] bed. These are flanked on either side by overfalls of the same w[illegible]

RUTMOO LEVEL CROSSING, GANGES CANAL

· sills, 6 feet higher, and on the extreme flanks are platforms ɔve the canal bed. These elevated platforms are 17 feet long ·cted with the revetment on the canal banks by inclined planes ·y. This escape dam is practically identical in construction ›rdinary scouring sluices at Myapur and other places. The through the sluices up to the height of 6 feet is 470 feet wide, ·en the levels of 6 and 10 feet it is 570 feet wide. Above that ·et wide. The closing and regulating of the opening in this is conducted by means of flash boards fitting into grooves. › gates are dropped rapidly, being constructed on a plan simi- Soane scouring sluices, but more crude in their method of tion. When not he water in the carried under and returned ıtmoo Torrent by means of a nage tunnel or siphon about long. Owing gh velocity of ; in the Rut- ·nt, there is no f silt in the › greater part ; being carried ;hrough it by of the flood The torrent in has been cut- ; on the down- ıd to stop this ion of levels 5 ›ars have been ; it, each about

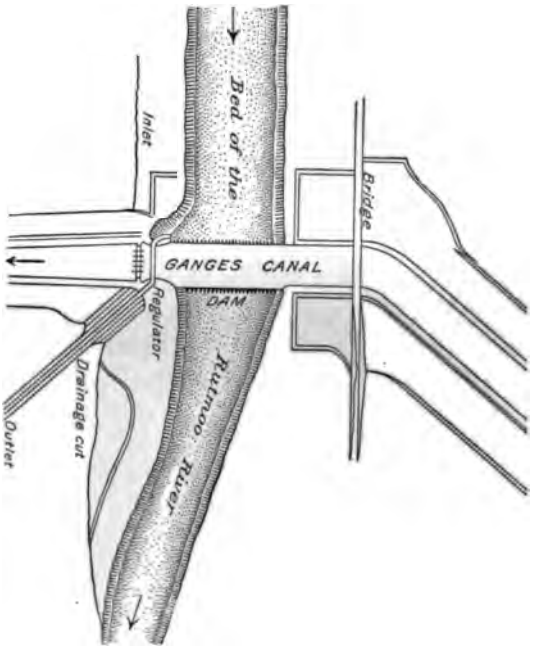


FIG. 31.—Plan of Rutmoo crossing, Ganges canal.

apart. These are composed of cribs filled with bowlders, acted as contemplated. The maximum flood anticipated arged through the Rutmoo Torrent is 25,000 second-feet. lating bridge across the canal below the crossing has 10 s, each of 20 feet, and in addition to this there is a roadway ·ming a bridge. There is about a mile of revetment walls, ; on blocks or wells sunk to a depth of 20 feet below the . This is protected by numbers of piles and cribs filled ders.

o Nulla on the twenty-first mile on the main western Soane ɔassed by a siphon aqueduct. This torrent is subject to ls. They are estimated on the basis of 6 inches of run-off

on the 57 miles of catchment, and the highest velocity is 8½
second. The siphon passage for the flood provides 1,103 sq
of water way disposed in 20 openings, each of 54 square fe
work consists of substantial masonry carried well beneath th
under the bed of the torrent and above ground for the supp
aqueduct, and is only a semisiphon carried under the aqu
indicated in the accompanying sketch (fig. 32). A simila

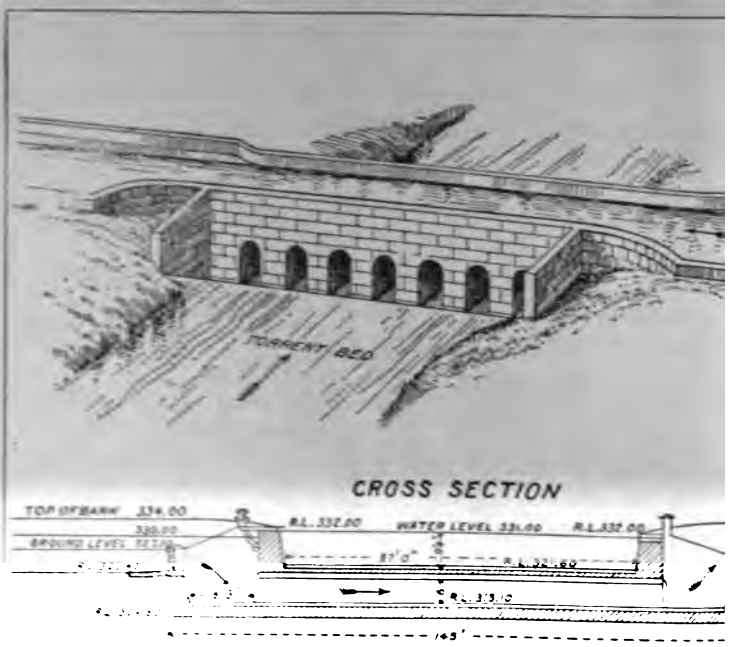


FIG. 32.—Kas Nalla siphon aqueduct, Soane canal.

that of a superpassage and siphon on the line of the
whereby the torrent is carried over the canal, the latter
inverted siphon. This work is indicated in fig. 46 (p. 171)

DISTRIBUTARIES.

Like the main canals, the distributaries or laterals are
designed and laid out by and are under the control of
engineers. From these the farmers take their private wat
and channels to their fields. Sir P. T. Cautley thus speak
in connection with the Ganges canal:

In our irrigation system the trunk and main canals with their gr
play the part of a reservoir to the distributaries. The latter hold th
the main canals of a system of distributary pipes in a town water
village or private water courses play the part of service pipes.

stribution from a canal is most economically effected
runs along the summit of a ridge so that it can suppl

ranches and to private channels on both sides of it (fig. 37). location in the case of a large canal can happen only in occa- l instances, but the secondary or distributary branches taken these principal canals can and should be made to conform to

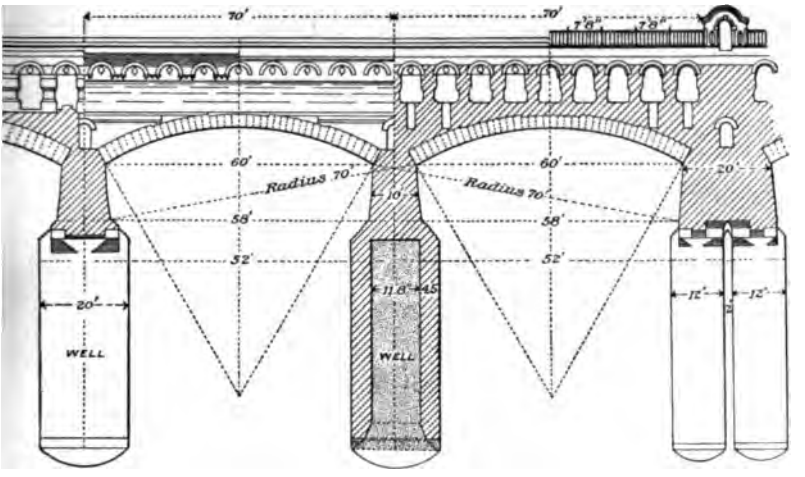


FIG. 33.—Nadrai aqueduct, Ganges canal.

ding lines between water courses. The capacity of the distribu- which then traverses each separate drainage divide is propor- ed to the duty it has to perform, the bounding streams limiting area it has to irrigate.

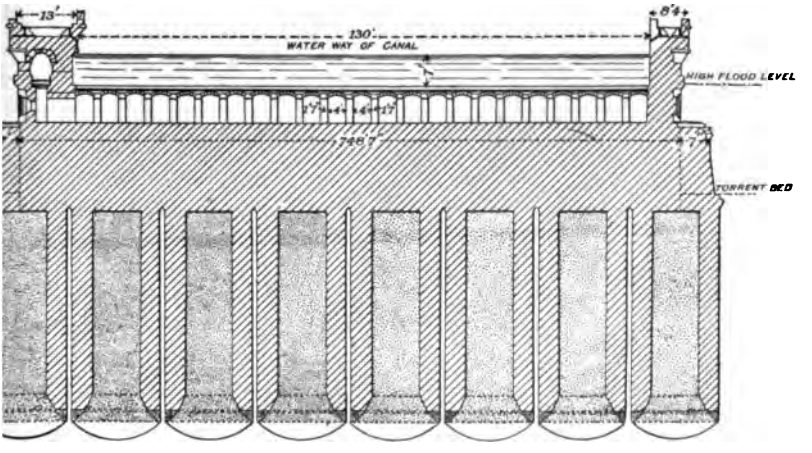


FIG. 34.—Cross section of Nadrai aqueduct, Ganges canal.

r the more complete and efficient distribution of water the engi- treats them as of as much importance as the main branches selves. Attention is devoted to the character of the soil trav- l, to the alignment, to the safe and permanent crossing of nat-

ural drainage lines, and to so maintaining the surface of the canal with relation to the ground as to command the largest irrigable area. In all well-designed distributary systems the capacity of the channels is exactly proportioned to the duty to be performed, the cross-sectional area being diminished as the quantity of water to be carried is decreased owing to its diversion by private water courses, though a sufficiently large margin is usually allowed for future possible development.

It is usual to take off the water of a distributary from the main canal as near the surface of the latter as possible. That is, the bed of a distributary should not be on a level with the bed of the main canal, the object being first to get the clearest water possible, which is found nearer the surface, and second to keep the bed of the distributary at as high a level as possible to admit of surface irrigation throughout its length. In level country great care is always taken in designing these distributaries that the natural drainage lines in which they tail shall be sufficiently large to accommodate any flood volume it may be necessary to pour into them, so that the distributary may be rapidly relieved during times of storms and the drainage lines shall not become clogged and flood the surrounding country. The slope of a distributary is usually planned to be as nearly as possible parallel to that of the district it traverses in order to avoid costly embankments and to insure the surface of the water being above that of the country. Falls are sometimes rendered necessary by the profile of the country, as is the case on larger canals, while escapes are introduced every 8 to 10 miles.

Distributaries as designed on the great Ganges canal have been made to conform as far as possible to a general design, which may be outlined as follows: The heads have been constructed at the points where bridges or falls were necessary, in order to economize in masonry construction. This location also insures their better inspection. The beds are generally from 2 to 3 feet above those of the main canal from which they are taken. These heads are designed as mere open gateways with grooves for the introduction of shutters or planks. No further design has been attempted for the regulation of discharge. The distributaries are divided into main lines and feeders. The first or main lines run parallel to the canal on both sides, and these parallel lines are met in their passage downward by feeders coming from the different distributary heads in the neighborhood. This principle of constructing parallel channels to the main canal is one which would not recommend itself for use in the United States, as the chief object, or rather the cause of their employment, has been the navigative character of the main canal. As the main canal must necessarily have a very low slope in order that the velocity will not impede navigation, and as these main canals at their heads below lock are usually sunk some depth beneath the surface of the adjacent country, it becomes

actically impossible to distribute water from them, and accordingly
e parallel lines have been employed, which, keeping near the surface
the country, facilitate the distribution of the water to other minor
annels. Where the canals are not primarily designed for purposes
navigation these parallel channels may well be dispensed with,
ough they are found on nearly all of the larger Indian works.

According to Major Brownlow, R. E., the greater the amount of
ater discharged by a distributary the smaller will be the proportion
cost of maintenance, for a channel 12 feet wide discharges more
an double that of two channels each 6 feet wide, while the cost of
trolling and repairing the banks will be half that of the two smaller
es. Experience proves that irrigation can be most profitably car-
d on from channels 18 feet wide at the bottom and with about 4
et depth of water. On the eastern Jumna canal, during the years
om 1858 to 1860, the expenditure on all the distributaries of 12 feet
ad width and upward was 0.123 of the revenue, while on all those
low 12 feet it was 0.223 of the revenue, or nearly double the first.
e relative value per cubic foot per annum from the same experi-
nts, on channels of respectively 12, 6, and 3 feet in width, was as
: 7 : 4. Increased action of absorption in small channels, with
inished volumes and velocities, accounts for the difference. The
th of water accordingly should be seldom less than 4 feet, and the
face of the water should be kept at from 1 to 3 feet above that of
surrounding country, not only to afford gravity irrigation, but
ause the loss by absorption is thereby diminished. This was
wn in the experiments referred to in the previous part of this
er, under the heading "Duty and absorption."

ndian engineers unite in condemning the practice of raising the
er in the channels to the surface of the country by means of dams
stops made by introducing planks into grooves made for that pur-
e. This practice, they say, converts a freely flowing stream into a
es of stagnant pools, encouraging the growth of weeds, the deposit
ilt, and an unhealthy condition of the neighborhood; and it is,
reover, extremely wasteful of water, since much of the latter is
ipated because of the loss of head. In designing the canal banks
width of the top of the bank should be sufficient to admit of easy
pection. On moderate-sized distributaries, such as those just
erred to, 4½ feet may be taken as the minimum width, and wher-
r the dimension of the channel will permit it this width should be
reased. Should the cutting be so deep that a berm is necessary,
s always well to let the latter slope away from the canal and be
ined off through the bank; the top of the bank, likewise, should
pe away from the canal, and not drain toward it, as in times of
vy storms much silt may be deposited in the canal from this local
inage.

Ordinarily the water for the village ditches is taken from the dis-

tributary by means of hollow wooden or iron pipes let into the bank of the canal and nearly flush with its bed. These are stopped at the outlet by a valve or plug. The heads of the distributaries on the modern canal systems are more carefully designed. They are usually constructed of substantial masonry works let into the canal bank and closed by a valve or other easily controlled shutter. In the North-west Provinces a series of standard designs has been prepared, an illustration of which is given (fig. 38). The heads of the minor branches or the private water courses are, like those of the distributaries, usually placed where the existing masonry works occur, as at falls or bridges, while the private channels head in simple wooden or iron

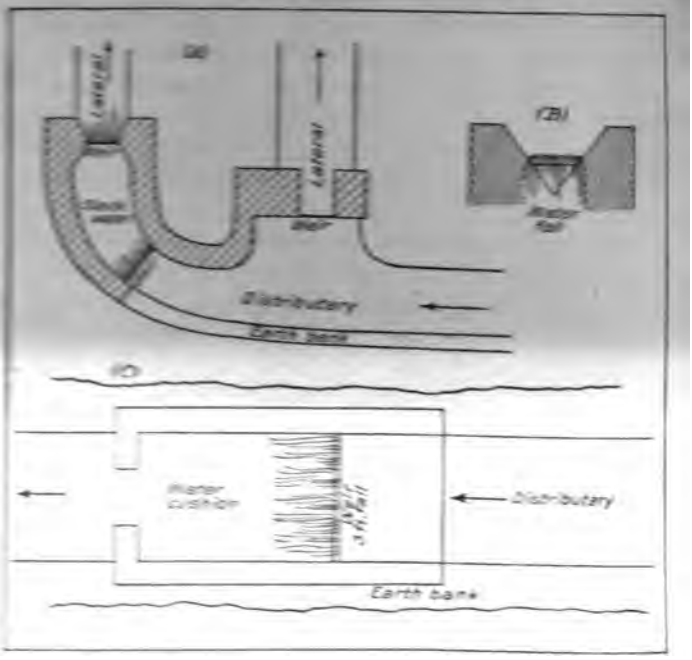


FIG. 38.—Plans of distributing head, Mutha canal, Bombay.

outlets. Substantial masonry falls are constructed at such points the grade of the surface of the country makes necessary (fig. These are usually simple vertical drops into a masonry well, and scouring is generally lessened by creating a water cushion at the tom of the fall.

In the Punjab and elsewhere rules have been laid down for the struction and estimate of the masonry works on distributa Among others are these: Siphon barrels shall have a sectional equal to the bed width plus one-half the full supply. Siphon shall have the same area as above, the depth being equal to 1½ the fall supply. The depth of the cistern at the foot of a fall in to form a water cushion shall equal one-third of the height o

as the full depth of the water. Thus with a fall 4 feet deep on a nal carrying 5 feet of water, the cistern depth will equal ½ (4 + 5) 3 feet. The minimum cistern length is qual to three times the pth counting from the drop wall to the reverse slope, which latter ll be 1 in 5. The width of the cistern must be twice the mean 'pth of the water in the channel, or twice the bed width plus the full 'pth.

While the water rate is at present charged in India according to the 'ea irrigated and the crop raised, it is universally conceded that it ould be fairer to charge for the water according to the quantity used, it can make no difference to the canal proprietors what becomes of 'e water after it has been delivered and paid for. The difficulties in 'e way of delivering water by actual measurement have been insuper-le, chiefly because no practical method of measuring water under

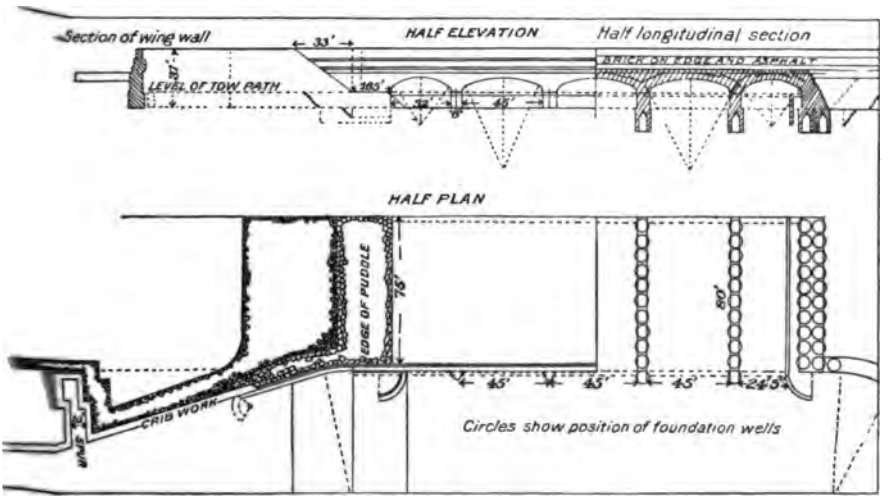


FIG. 36.—Sasoon superpassage, Sirhind canal.

a constantly varying head has yet been devised. On all the older-established canal systems, especially when the supply entering the head of the canal is insufficient for the demand, a system called "tatil" has been established. This may in general be said to consist in a mode of regulating the amount of water given to the irrigators by the canal officers closing their outlets for successive periods of time in regular rotation. Each cultivator is compelled to take the water when his turn arrives, be it in night or day, or else lose his share of water at that time. It is considered the best practice to impose these tateels on long portions of a distributary at once, as short ones have very little effect in forcing water down to the tail of the canal. In their operation an irregular period of rotation is employed. Thus the outlets may be closed in the first length of the canal for four days, on the second portion for *three days, and so on*, and then this order may be reversed, the

onstructed earth ditches to branch channels, which are ordinary run-ays roughly excavated in the soil.

Rice is everywhere irrigated by dividing the land into small squares r blocks in an irregular checkerboard fashion. These are usually ot less than 20 and rarely 100 feet square, depending largely upon ource of supply and slope of country. These blocks are separated y low earth banks about 1 foot in height with cuts opening through hem from one block or field to another. Where the slope of the sur-ace is very light extensive fields may occasionally be seen within one lock. On hillside country the steeper slopes are terraced by the con-truction along a contour line of a low embankment about 1 foot in eight. These terraces retain the water from floods or storms, sub-merging the rice crop to a depth of several inches, thus acting as miniature tanks. In the more level rice country the various blocks are flooded from the canals, the rice always being submerged to a considerable depth.

In irrigating sugar cane an effort is usually made to obtain a freer flow of water than can be obtained by the above method, though as in the case of rice cultivation this crop requires a great deal of water and it is permitted to stand to a depth of several inches over the sur-face of the ground. Wherever the slope will permit, numerous cross furrows are plowed or narrow ditches run throughout the field of grain or cane in such a manner as to permit the water to flow in a thin layer over the soil, that which is not absorbed being caught up and utilized by the next lower ditch. Excepting in the irrigation of rice or occasionally of sugar, the land is almost invariably divided by some method of gridiron work of furrows and ditches as will most conveniently cover the area to be irrigated, excepting in cases where the water is sprinkled by hand.

In an interesting paper discussed by Mr. Baldwin Latham before the Institution of Civil Engineers,[a] he gave a novel description of the cir-culation of water in soil as shown by some experiments which he had made with the object of discovering the precise difference between the application of water in rice irrigation where it stands stagnant on the land and other irrigations where a constant current is kept moving. The result of these experiments showed that where a surface velocity was created it would promote a circulation of water throughout the soil, a matter of considerable importance, as by that circulation manu-rial matters were equally distributed while other material was removed which was not required by the plant, and which if allowed to stagnate would produce those ill effects shown when cultivating rice. The experi-ments were conducted in a water-tight glass tank which was filled with fine silver sand into which was poured a solution of perchloride of iron. Over this a solution of nutgalls was allowed to pass slowly and the course of the circulation could be readily followed, as the point of

[a] Discussion of irrigation in northern India: Proceedings Institution of Civil Engineers, London, vol. 35, p. 172.

contact of the two mixtures produced tannate of iron or ink which portrayed a perfect diagram of every stage of the experiment. The result of the experiment showed, among other things, that where there was an inclination of the surface resulting in the production of natural currents over it, a circulation through the soil took place.

Another tank experiment was made giving the conditions of a rice irrigated field. The same materials were used, but the tank was kept level, and it was found that after six months' contact no discoloration of the sand had taken place to a greater depth than one-fourth of an inch, showing there had been no displacement of the water occupying interstitial spaces in the sand. Mr. Latham said that the circulation of the water through the soil, on all land having an inclination, had a marked beneficial influence on irrigation, as conclusively shown from the practice adopted for generations in the irrigated districts of Piedmont and Lombardy, Italy, where, as the headwaters are left, it is customary to increase the natural slope of the irrigated beds in order to create a greater velocity, and hence a greater circulation through the soil.

CHAPTER VIII.

STORAGE WORKS.

CLASSES OF WORKS.

The employment of storage works in connection with irrigation ɔjects is resorted to in order that an assured constant supply of ·ter of a given amount may be furnished by their aid to any area irrigable lands during each and every season, regardless of the ıount of rainfall occurring and of the question whether it be an normally wet year or one of unusual drought. Where great pernial streams flow through land to be irrigated there is never any cessity for the addition of storage works as a protection against ɜ failure of the water supply, but where valuable lands are to be igated and the source of water supply is from intermittent or very all streams, it becomes necessary to supplement the perennial flow curring in these during the irrigating season by the storage of the od or waste waters lost during the remainder of the year. This d is attained by damming the stream in some place where it will od a broad valley and create a large artificial lake or reservoir, or diverting its waters to some depression or other reservoir site ıere it can be conveniently stored.

Two classes of storage works are generally referred to by Indian gineers—namely, reservoirs and tanks. There seems not to be any ; rules for distinguishing the two, as works sometimes called tanks ɜ frequently larger than the largest reservoirs. Merely for purses of convenience in discussing the subject, the author will adopt ɜ common practice of considering reservoirs as bodies of water ·ained by a dam constructed wholly of masonry, while tanks are ·rage works the dams of which are constructed wholly or in part of ·th. Reservoirs are usually deeper than tanks and are constructed running and flood streams, while tanks are generally shallower l are constructed on minor and unimportant streams, the flood charges of which are so small that all the water can be either ted or safely wasted, thus not endangering the integrity of the n, or they are constructed in depressions on the plains or inter·es adjacent to the streams from which water is diverted to them. n general, works for storage purposes may be filled from canals erted from some large stream or filled directly from the discharge the catchment basin of the stream upon which they are located.

The location of, necessity for, and probable return from the co tion of a storage work is always a subject which receives ma ful thought, both from the engineering and financial departm the Indian government, before the work is finally sanction undertaken. Many different considerations have first to be di and weighed in deciding the location. The work should be pl a sufficient elevation above the lands which it is intended to to allow the delivery of the water to them by natural flow. T age work may be so situated that it is immediately adjacent lands, in which case a very short canal will serve them, or it at some distance from the lands to be irrigated, thus requiri line of canal. Again, the storage water may be turned back natural drainage channel when required, and be permitte

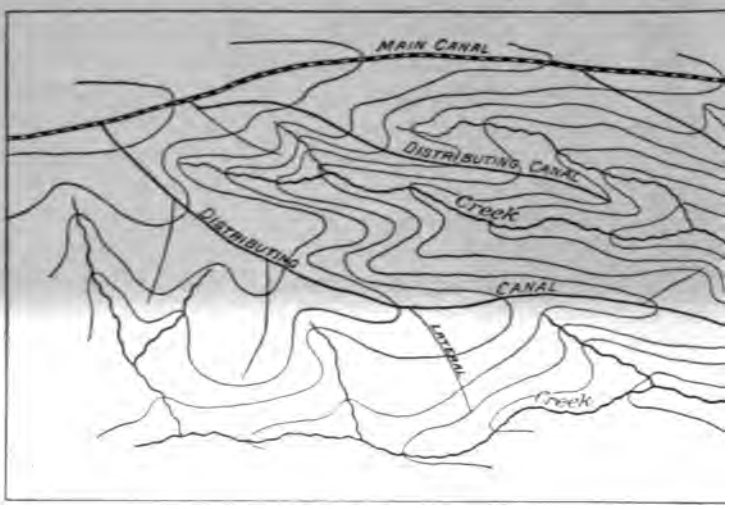


FIG. 37.—Drainage map, showing arrangement of distributaries.

down to the neighborhood of the lands where it will be agai for irrigation purposes. The second case mentioned ma costly if the canal line be long, but the last is invariabl expensive method, as it is wasteful of water, the loss o greater by absorption and evaporation than in a well-c canal, while there is incurred the additional expense of a weir at the point where the stream is turned from the natur into distributing canals.

Having decided upon the location of the lands to be irri knowing their area, the first consideration attacked by th is the location of the storage site. This may be discovered a time has been spent in making trial surveys and investiga order that it shall be desirable for its purpose it must be character that the cost of its construction will not be prohib considering the source of the water supply from which to fi

age work a thorough hydrographic survey of the catchment basin above the reservoir is necessary, in order to discover the maximum and minimum precipitation, the percentage and rate of run-off, and the total quantity of water available for storage. Stream gagings are maintained for a few years, and all possible effort made to discover the volumes of maximum floods as well as the total quantities of water discharged. To these ends a good topographic survey is first executed, as from the maps thus constructed the relation can best be studied between the irrigable land and the reservoir site and the latter and its catchment area. These maps enable the engineer to measure the areas of the catchment basins and to calculate the discharges from these areas, provided the rate of run-off is known. The Indian government has already constructed over most of its territory a good topographic map, on a scale of 1 mile to 1 inch, upon which the topography and outlines of hills and valleys are indicated in hachures, and numerous elevations are marked at prominent towns, passes, and mountain peaks. In addition to this, much of the more densely inhabited portion of the peninsula has already been surveyed and mapped for revenue purposes, on the large scale of 4 inches to 1 mile. With the aid of the latter map it is possible to determine with much accuracy the various fields and plats of land which are to be served by the irrigation scheme and their general relation to the distributory channels, while the smaller scale maps enable the engineer to solve all the general problems in connection with the catchment basins, streams, general location of storage site, and the general course which the distributing canal or other medium must take in order to conduct the water to the lands to be irrigated. Such maps as these are of the greatest possible service in the designing of any scientific and general scheme for the development of the irrigation resources of a country, and enable the engineer, like the general in command of an army, to muster all his forces, look over and conceive at a glance the problem to be attacked, and decide upon the best mode for the utilization of all the resources at his command for the general good of the whole area to be served.

After the preliminary problems have been solved the more detailed considerations are investigated. In locating the dam site it is necessary, first, to have above it the largest possible basin or valley, with as low or flat a slope as is obtainable, in order that a maximum storage capacity may be had. The site should be so chosen that it shall require the shortest possible dam to close it and yet afford a sufficiently wide waste weir to discharge the maximum flood without injury to the dam. Finally, it must be so located that the geologic formation shall be favorable. The dam must not be founded on a porous formation, and, if of earth, the material of the abutments and foundation must be of suitable quality to afford an impervious connection. If a masonry dam, it should be founded on solid rock. A study of

the general geology of the neighborhood in order to ascertain wh the valley which is to be used as a storage site is an anticlinal or clinal valley, or one produced by simple erosion, is of great impor as indicating the dip of the underlying it and the pos value of the same as a noncon ing medium for the water stor the valley. Material for the struction of whatever class o is decided upon must be co ient to the site in order to r to a minimum the cost of t portation and construction.

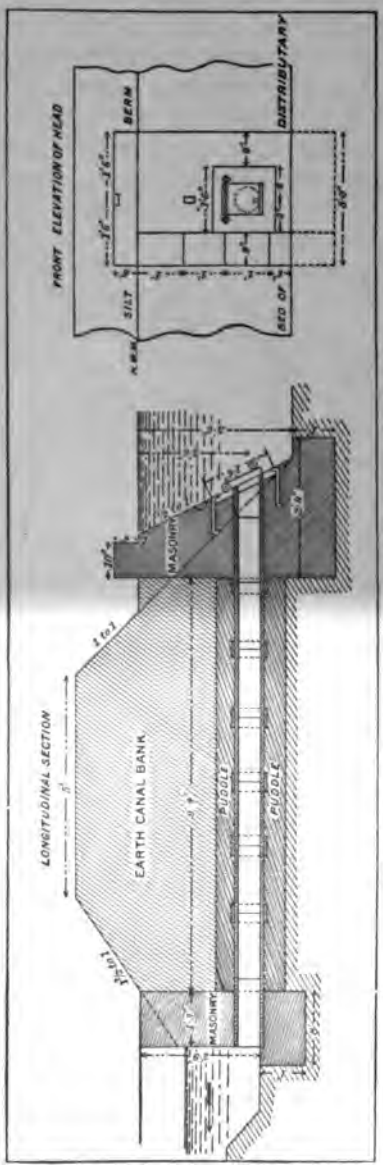


FIG. 38.—Standard masonry outlet for distributaries, Punjab.

* In studying a catchment the Indian engineer has rec to a few simple formulas to in determining the flood disc from the area under cons tion, and as a check on the r obtained from local observ The following are two of th mulas most used:

Ryves's formula, $D=C \sqrt[3]{}$

Dickens's formula, $D=C \sqrt{}$

in which M represents the of the catchment basin in miles, C is a coefficient depe for its value upon rainfal slope of ground forming the etc., and D is the resultin charge, usually shown in te cubic feet per second. It be borne in mind, howeve no such formula can be s applicable with the same cient to areas of varying even in the same part of the try and under the influence same intensity of rainfall, the other circumstances, s the slope of the ground, cha of the soil, etc., be approximately similar. The chief difficul be found in the selection of a suitable coefficient, and a few of for different districts in India, which correspond in general cha istics to the arid region of the United States, are here given.

regions where maximum recorded rainfalls of from 3 to 6 inches
enty-four hours have occurred, the coefficients for Dickens's
ula, which have been settled upon, are about as follows:
ximum rainfall 3.5 to 4 inches, in flat country, C = 200; mixed
try, C = 250; hilly country, C = 300; and for a maximum rainfall
nches C varies between 300 to 350, according to the nature of the
try. The corresponding number of inches of drainage for a stand-
rea of 5 square miles from these figures would vary, for the first
p between 5 to 7.5 inches, and for the second group between 7.5
5 inches. For Ryves's formula the coefficient varies between 400
500, and for very hilly areas, where the maximum rainfall is high,
ay reach as high as 650. The flood discharges are invariably
ortionately less for large basins than for smaller ones.
very interesting paper on this subject of maximum flood discharge
catchment areas was read by Mr. James Craig before the Insti-
n of Civil Engineers in 1884.[a] The details of the argument entered
in this paper are too elaborate to be presented here. In general
are an amplification and discussion of results obtained from
usly shaped catchment basins, showing new methods of deter-
ng the loss of discharge other than those obtained by the two
ulas given above.
order to show the character of the detail connected with the
us investigations and problems to be solved when the value of or
sity for the construction of the storage work is under considera-
in India, attention will be called to a few of the questions which
ndian engineer is directed by his superiors to investigate. These
s and others not included herein are laid down by General Mul-
chief engineer of irrigation for the Madras government in India,
he guidance of engineers in that presidency.[b] The general cir-
tances of investigation are whether the valley or drainage area
r consideration is partially occupied by tanks or is unoccupied.
e will be some prima facie evidence available about particular
or what the inhabitants suppose would be suitable sites. It may
sired to supply water to a definite area of new land to be irri-
l or to land that had a previous supply which has been stopped
e silting up or destruction of existing tanks.
the preliminary information the average rainfall of the country
ts character are obtained from any records which may be in exist-
. The irrigation duty of the drainage area in square miles or
other unit is ascertained, as well as the quantity of water deriv-
from this unit of catchment area and the average rates of assess-
for irrigable lands. The preliminary investigation includes, as
e stated, a study of the atlas sheets of the survey of India and
e revenue survey maps, an examination in detail of the country

---

ximum flood discharge from catchment areas: Proceedings Institution Civil Engineers,
n, vol. 80, pp. 201-220.
gation Manual, E. F. Spon, London, 1890, p. 55.

in order to ascertain the most suitable reservoir sites, and an examination of the drainage lines thence downward. To be considered, sites usually must be in a valley which has a moderate longitudinal slope, with moderate transverse slopes on either side of the axis of the valley, must admit of a moderate length of dam with suitable abutments at either end, a probable moderate depth of water and corresponding height of dam, suitable material for the formation of the dam, and possess facilities for the disposal of surplus, preferably by wasting over detached saddles through rock soil or subsoil. Land below the site must also be available for irrigation, and there should be an absence of much or valuable cultivation and of villages within the probable area of the water spread. Whether water storage may be obtained on financially advantageous terms will depend largely on the difference between the values of the land when irrigated and when not irrigated. In order to ascertain this difference in value it is necessary in India, as in America, to know what area a given quantity of water can irrigate, what that area will pay for the water, and what the storage and distribution of the water will cost.

In various discussions of storage capacity and water duty, hereafter to be entered into, the author will for convenience use the storage unit employed by the United States Geological Survey, 1 acre-foot. This is 43,560 cubic feet, or the quantity of water which will cover 1 acre in area to a depth of 1 foot. In dealing with large quantities of water, such as those stored in great reservoirs, it is inconvenient and troublesome to speak of capacities in millions or billions of cubic feet, and the much smaller figures which will be dealt with by using the acre-foot as the unit of measure make the subject-matter more intelligible. Likewise the area of land irrigable from a given amount of storage water can be more conveniently considered; that is, the duty of the storage water can be spoken of in more convenient terms if we refer to the duty performed per acre-foot. Thus, in portions of Colorado the duty of an acre-foot, providing the distance which the water has to be carried to the land is not so great as to cause excessive loss by absorption, may be stated as being 1¼ acre-feet per acre.

As an instance of the cost of storing water, the investigations of the Bombay engineers show that in favorable cases where water has been stored in reservoirs of the first class 56,700 cubic feet, or about 1⅓ acre-feet, of water has been stored at an average cost of $1. The cost of the water, however, when served to the field will be considerably above this, as the loss due to evaporation and absorption in the reservoir during storage period and the loss due to the same causes in conveying the water through the canals to the fields to be irrigated must be included in the estimates. In this same locality in Bombay, after considering these losses, it appears that about 38,000 cubic feet of water can be stored at an average cost of $1.

ainfall is always more than sufficient to fill the reservoir. The . on the right bank is 99½ miles long, and is designed to discharge econd-feet at the head; however, its usual discharge is somewhat

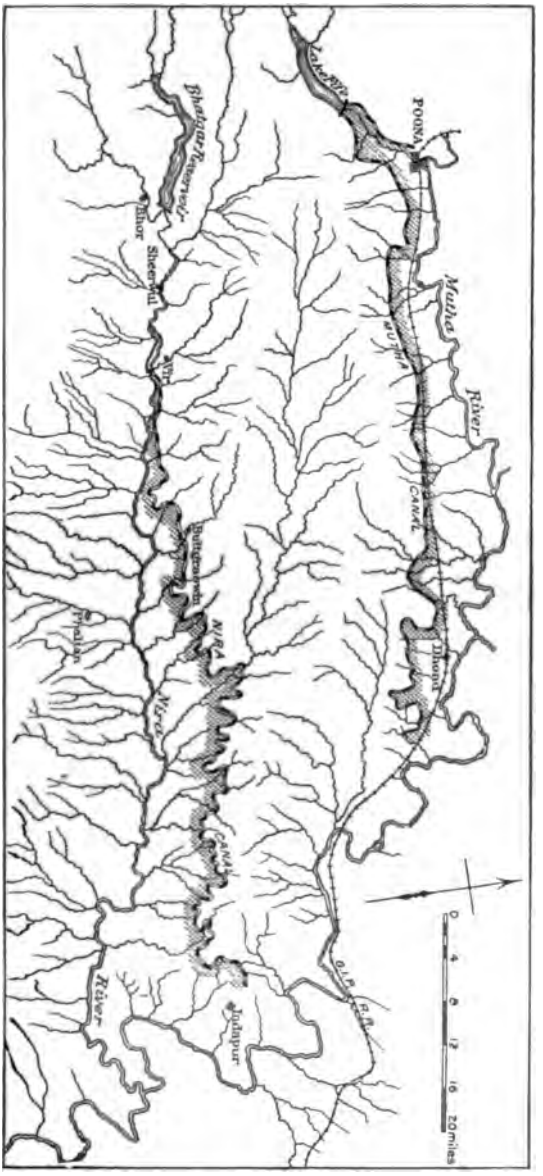


FIG. 30.—Plan of Mutha and Nira irrigation projects, Bombay.

while if necessary it can be increased to as much as 535 second-
This canal passes through the town of Poona and commands 00 acres of land entirely within the dry zone of the Deccan,

where the rainfall seldom exceeds 20 inches. In this area the variations in the rainfall and risks of drought are as great as the absolute rainfall is small. The left-bank canal is but 14½ miles in length and extends but a short distance beyond the town of Kirkee. It commands an area of 4,300 acres and the discharge at the head is 38 second-feet.

The reservoir is formed by a masonry dam founded on solid rock. This dam is constructed of uncoursed rubble masonry. Its total length is 5,136 feet, of which 1,453 feet are used as wasteway. Its height above the river is 98 feet, while its maximum height above the foundation level is 108 feet. The crest of the wasteway is 11 feet below the top of the dam, thus giving a maximum storage depth of 97 feet. The dam backs the water up the valley a distance of 14 miles. The available contents of the reservoir are 75,500 acre-feet, and the area of water surface exposed is 3,681 acres. In order to command a sufficient elevation the beds of the canals are taken off at an elevation of 59 feet above the river bed or bottom of the storage reservoir. Thus the available depth of storage is but 29 feet. The river above the reservoir has a catchment area of 196 square miles, over which the rainfall is so great that only one-sixth of the whole discharge of the river is used. The design of the dam is unquestionably crude. As at first constructed it was 14 feet wide on top, with straight slopes on either side of 2 on 1 downstream and 20 on 1 upstream. The dam soon showed signs of weakness, and to strengthen it a great bank of earth 60 feet wide on top and 30 feet high was piled up against its lower face. The line of the dam is built in several tangents, with changes of top width for each, according to the height of that portion of the dam, the points of juncture of the various tangents being backed up by heavy buttresses of masonry. The cost of this structure was about $1.75 per cubic yard, and its total cost was $630,000. While under construction a temporary wall of masonry was erected at some distance below the main dam in the river bed, which was built up to a height of 50 feet. The object of this was to form a temporary water cushion for the floods to fall on, so that they should not undermine the main dam while the wasteways were being prepared.

The discharge of water from the reservoir into the right-bank canal is regulated by ten sluices, each 2 feet square. These sluices are closed by iron shutters and are operated by means of capstan and screw from the top of the dam. There are in addition eight circular sluices, each 2 feet 6 inches in diameter, which are 1.33 feet lower than the canal sluices and are designed to supply water to turbines for mill power. These latter discharge into the canal through the turbine chamber. Three sluices of a similar pattern to the canal sluices mentioned are at the opposite end of the dam, for the supply of the left bank of the canal.

The right-bank canal has a bottom width of 23 feet and depth of 8 feet, though its usual supply of water is about 5 feet. Its fall is 4

ıches per mile to Poona, at which place there is a drop of 2.8 feet, hich is utilized by means of an undershot water wheel to drive pump-g machinery for the supply of water to the town. The canal is car-ed through Poona in a tunnel excavated in rock. At the fifty-first ile the canal supplies Matoba tank, which is constructed as a relief ork and commands an area of 8,550 acres of irrigable land.

The Mutha project was designed and has been operated as a produc-ve work, and was constructed from borrowed capital. As originally timated for, the total cost of the work, including land compensation, as to have been $2,664,000. The estimated revenue, including the venue from mill power and water supply to the city of Poona, was to ve been $207,000, or 7.78 per cent on the capital outlay. The total st of this work to the end of 1889 has been $2,082,000. The working penses were, in the year 1889, $2.08 per acre irrigated; the gross venue from irrigation was $37,000, and the total net revenue was 2,000, including the revenue from all other sources, or 3½ per cent terest on the capital invested.

NIRA PROJECT.

Bhatgur reservoir is located in the Presidency of Bombay, about 40 iles south of Poona, on the Yelwand River just above its junction ith the Nira. The topography of the country thereabouts, in its hysical characteristics, its climatology, and the appearance of its vege-ation is very similar to that in northern Arizona in the neighborhood of 'each Springs or Hackberry. It consists of high mesas or table-lands, erminating in abrupt and nearly perpendicular rock slopes, and cut ito by deep canyons, which open out rapidly onto broad bottom lands nd valleys, leaving the mountain masses standing out boldly like the ains of great old fortresses.

The frequent failure and the general uncertainty of rainfall in the ortion of the Poona collectorate through which the upper Nira River ows caused Colonel Fife to turn his attention to devising some means or supplying this district with water for irrigation. Surveys made nder his direction in 1863 showed that the system of small tanks 'hich had been generally considered applicable to this region was, nancially speaking, impracticable, as the slopes of the smaller val-eys are as high as from 30 to 50 feet per mile. The result of the etailed surveys then made was that these tanks at best afforded but limited area of irrigation, while a tolerable site for a tank was almost avariably occupied by gardens irrigated from wells, thus rendering he land expensive.

Preliminary surveys for the Nira project were made in 1864, but vere soon discontinued. They showed that the canal must commence ıear the town of Shirwal. In 1868 a committee was appointed to nvestigate this scheme further, and the result was that it reported *he district to be drought* stricken, and said it would be advisable to

have surveys made at once for the construction of a reservoir on the Nira River, with a canal from the same. Surveys were resumed in the same year under Lieutenant Buckle, R. E. These were continued for some time, and were finally taken up by Mr. J. E. Whiting, C. E., under whose direction the project was finally constructed. Mr. Whiting's observations and surveys proceeded until 1871. They included the examination of several different sites and comprised detailed surveys not only of these sites, but of river-gaging and rainfall observations, and the cross sectioning of the valley along the canal line. The scheme as finally submitted, and as now constructed, consists of a reservoir on the Yelwand River and of a canal heading at Vir, on the Nira River, 19¼ miles below the reservoir site, the canal being 129 miles long and discharging 945 second-feet at the head (see fig. 39).

The catchment basin above the dam site has an area of 128 square miles, and the fall of the river bed within the reservoir limits is 5 feet per mile. The water in the reservoir is backed up the valley a distance of 15 miles, and its total capacity is 126,500 acre-feet. The dam is 4,067 feet in length, and is composed of the best uncoursed rubble masonry laid in hydraulic cement. It is 127 feet in height above its foundation and its crest is 8 feet above high-water mark. Its extreme bottom is 74 feet wide, and the top is 12 feet, and is intended to be used as a roadway. The dam is designed on a modern cross section, by a formula very similar to M. Bouvier's (fig. 40). When full the pressure on the toe is 5.8 tons per square foot, or 90.8 pounds per square inch, and when empty is 6.7 tons per square foot on the heel of the dam. The water supply is such that this reservoir can be filled eight times in the year. Accordingly, it is evident that there is an immense volume of water to be wasted. The alignment of the dam curves in an irregular manner across the valley so as to follow the outcrop of rock on which it is founded. These foundations are excavated to a depth of 2 feet in the solid rock, which has required an excavation sometimes as deep as 30 feet in order to reach homogeneous material. The greatest flood over the dam may be 50,000 second-feet, and this is passed off by 2 wasteways and 20 undersluices. The wasteways are constructed at either end of the dam, in the body of the dam itself, and are arched over so that the roadway is continuous above them. Their total length is 810 feet, and the flood may pass 8 feet in depth through them. The northern wasteway, that on the left bank, consists of 45 arches of 10 feet span each which can be closed by automatic falling gates. The wasteway at the south end consists of 36 arches, with the same dimensions and construction as the others. Jutting out from the main dam on the downstream side, in such a manner as to inclose these wasteways, are constructed walls of masonry which guide the discharged flood water into separate channels, which carry it into the rivers below the main dam.

Of the undersluices (Pl. XIX), 15 are constructed in the center of

BHATGUR DAM, NIRA SYSTEM, BOMBAY.

dam at its deepest point and are placed 17 feet apart, each being by 8 feet in dimensions, with their sills 60 feet below the high-water ie. With this enormous head these undersluices will discharge ,000 second-feet, which is an average maximum flood, and they have ccessfully withstood several years of flood without injury to the ints of the ashlar masonry with which they are lined. Under full ad the velocity through these sluices is 36 feet per second. Above is row of 15 undersluices, and near the surface slope of the valley, re two others of the same dimensions, one 2 feet above the main row nd the other 50 feet above the main row. These sluices are con-tructed, as are the main sluices, with a lining of the best asnlar

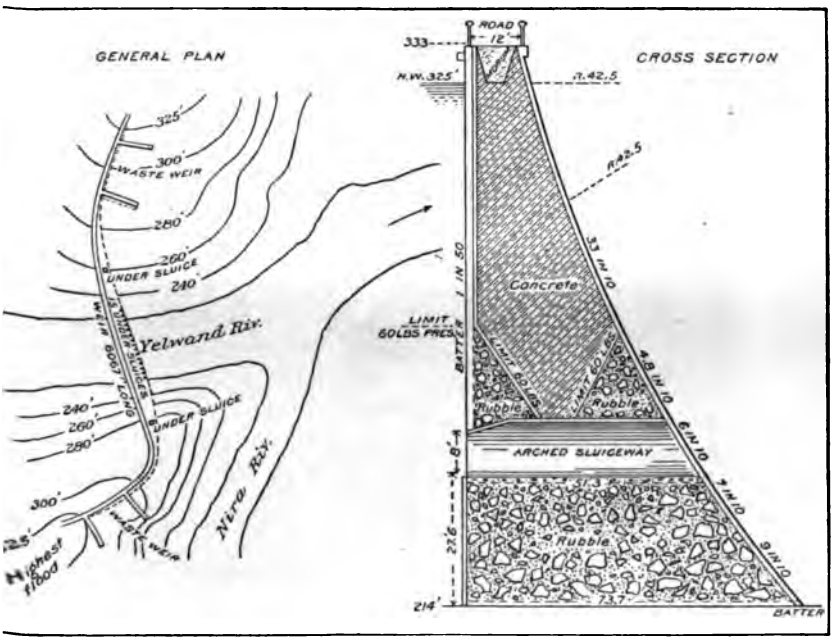


FIG. 40.—Plan and cross section of Bhatgur dam, Nira system, Bombay.

asonry, with pointed joints. They are closed by iron gates, which ide vertically. These gates weigh 2 tons each, and are operated by eel screws worked from above by a female capstan screw operated hand levers. The gates are protected from injury by floating jects by means of stout gratings of wood on the upstream entrance. here is 30 feet of idle space below the undersluices, and this is pected to fill up with silt.

The object of these sluices is primarily to discharge the water of the servoir, which then flows for nearly 20 miles down the Nira River to e diversion or pick-up weir at Vir, which turns it into the head of e Nira canal. Fewer sluices would have accomplished this end, but ditional ones were constructed with the object of keeping the reser-

voir above them free from sediment. This can be accomplished only by leaving the sluices open when much sediment is carried in suspension, and it is very doubtful if they would clean the reservoir of silt if it were once permitted to fill up.

Mr. A. Hill, superintending engineer, says of the scouring effect of these sluices:

Scouring sluices have little effect unless the area of the openings is great compared to the area of the floods. To remove silt already deposited they are useless, as has been proven by the manner in which they have silted up at Lake Fife and at Vir and other places where their area is small compared with that of the area of the floods. At Bhatgur they are intended not to remove silt deposited already, but to prevent its deposit by carrying it off while in suspension. If the dam is

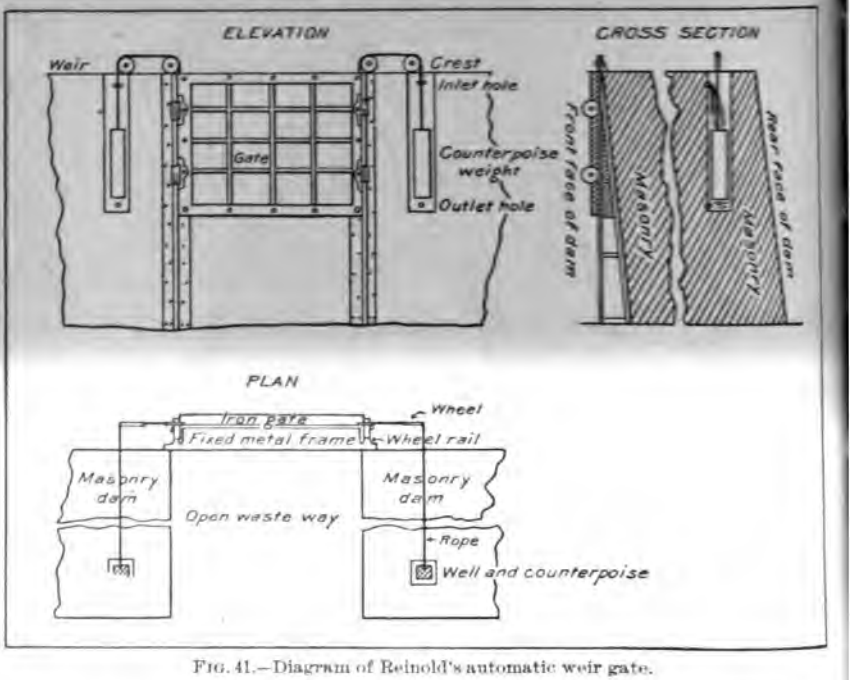


FIG. 41.—Diagram of Reinold's automatic weir gate.

high and the discharge of the undersluices will keep the flood level below the full supply level, then they will be efficient. If the dam is low and the sluices will not keep the flood level below full supply level, they will have little effect.

Experience on the Betwa reservoir and elsewhere bears out these conclusions, with the addition that their scouring or preventive effect is felt a very few feet to either side of the sluices, and silt will deposit close to their entrance. In other words, they do little more than keep an open channel above them.

The automatic sluice gates which are to be used on the wasteway of this dam are peculiar, and are well worth describing. They are patented by Mr. E. K. Reinold, their inventor, and their object is that when the flood reaches its maximum height, 8 feet below the

crest of the dam, the gate shall be entirely open, and as the flood subsides the gate shall automatically rise until it is entirely closed, thus adding to the reservoir capacity by the depth of the wasteweir. The gates are 8 by 10 feet, and they thus increase the depth of this reservoir by 8 feet. Where water is valuable such an expedient may be of the greatest financial importance.

These gates have been in successful operation since about 1892, or for ten years, and have worked admirably. So much so, in fact, that similar gates are being placed on the Lake Fife dam, and have been

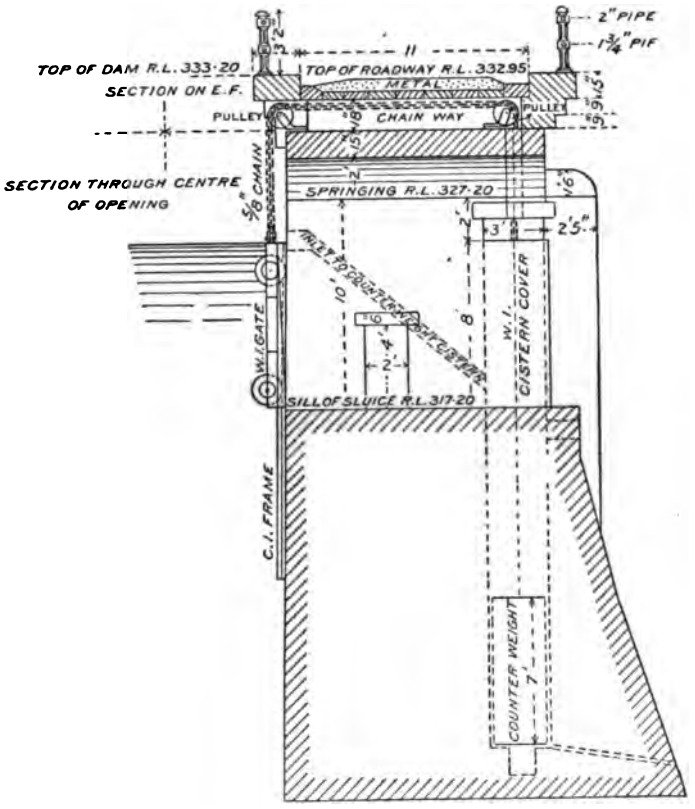


FIG. 42.—Section of automatic gates and crest, Bhatgur dam.

planned for others. The leakage at Bhatgur has been too slight to be taken in account.

The gate has two contact surfaces, one on the standard face against which it presses, and one on the face of the gate. These surfaces slide parallel to each other and are the surfaces of inclined planes. The gate rests on wheels running on rails and the axes of these wheels are parallel to the line of rails and at a slight angle to the contact planes, so that the latter do not touch until the gate is fully raised or closed, thus permitting by leakage a large amount of the flood water

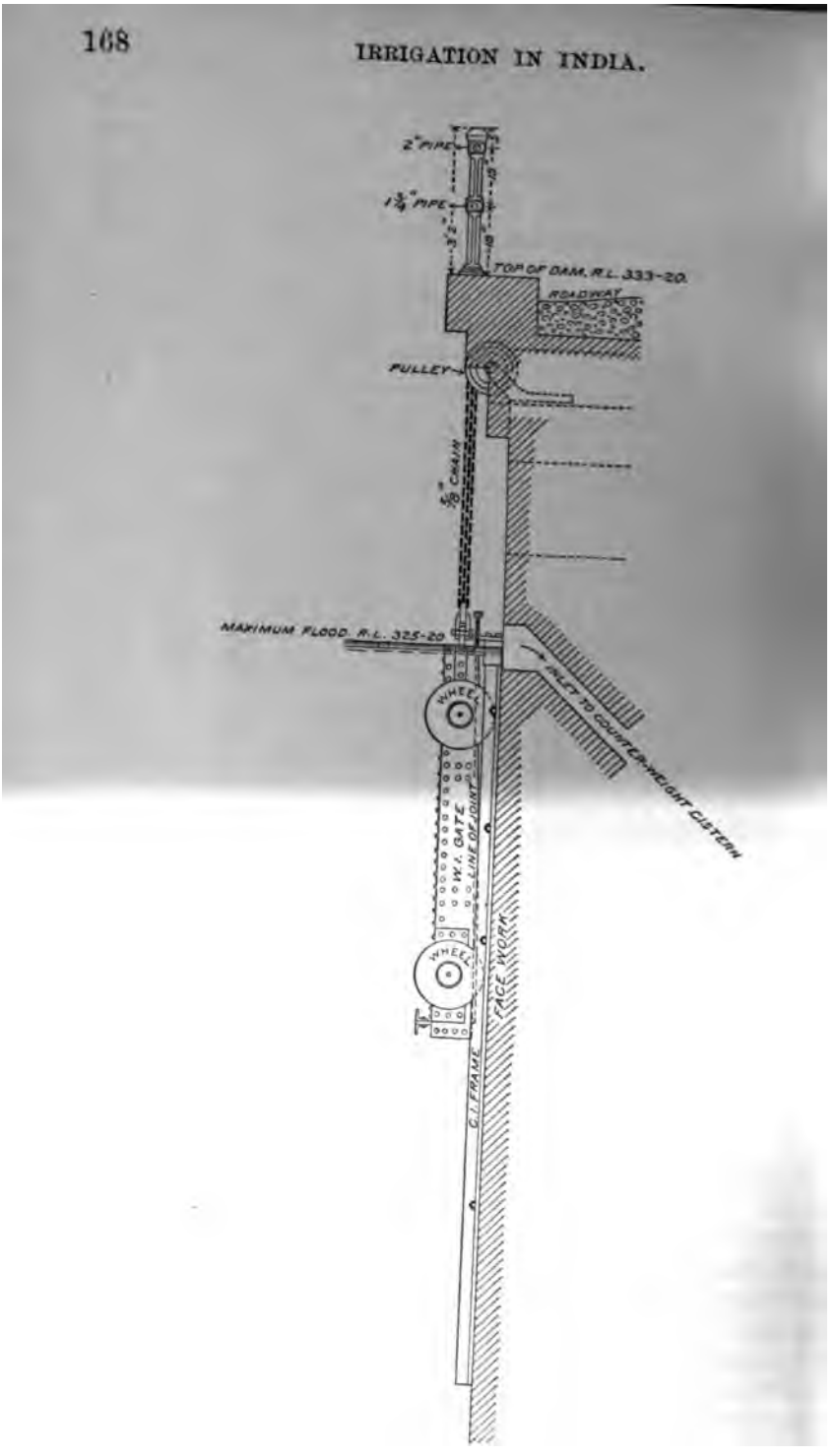


FIG. 43.—Detail of automatic gate.

A. VIR HEAD-WORKS, NIRA SYSTEM, BOMBAY.

B. KURRA AQUEDUCT, NIRA CANAL.

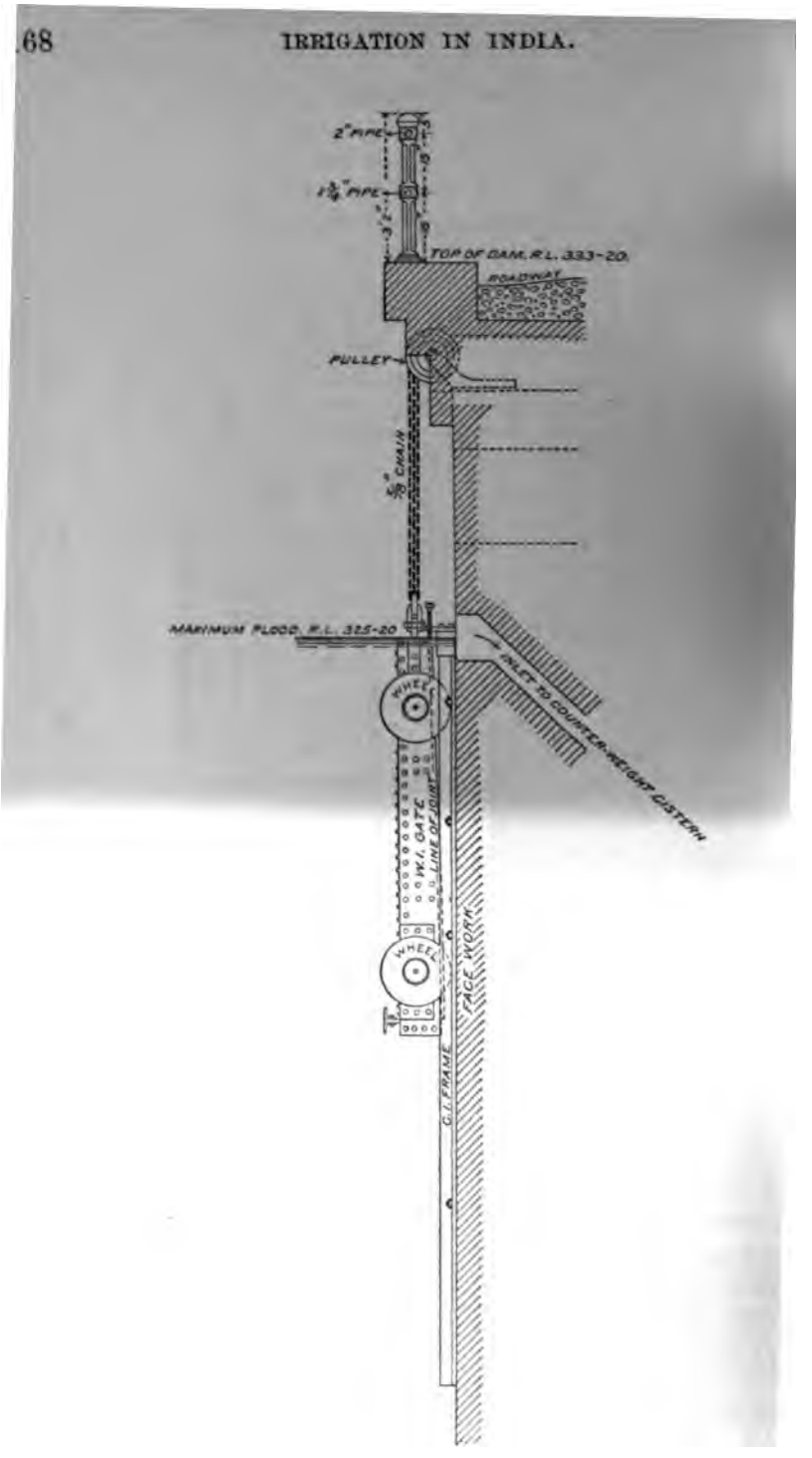


FIG. 43.—Detail of automatic gate.

A. VIR HEAD-WORKS, NIRA SYSTEM, BOMBAY.

B. KURRA AQUEDUCT, NIRA CANAL.

run out of them until the last moment. The accompanying illustrations (figs. 41–43) explain the operation of the gate. It is automatically operated by means of counterpoises balanced in water cisterns, the weight of which exceeds the weight of the gate by a little more than the amount of the friction, and they act by displacing their volume in water in the cisterns in which they plunge, thus lessening their weight by that of this volume of water. As the water flows over the top it flows simultaneously into the cast-iron boxes in which the counterweights hang, through inlets placed on a level with the gate top. This water entering the cisterns reduces the weight of the counterpoises, and the gate then, being the heavier, sinks, opening the waste-

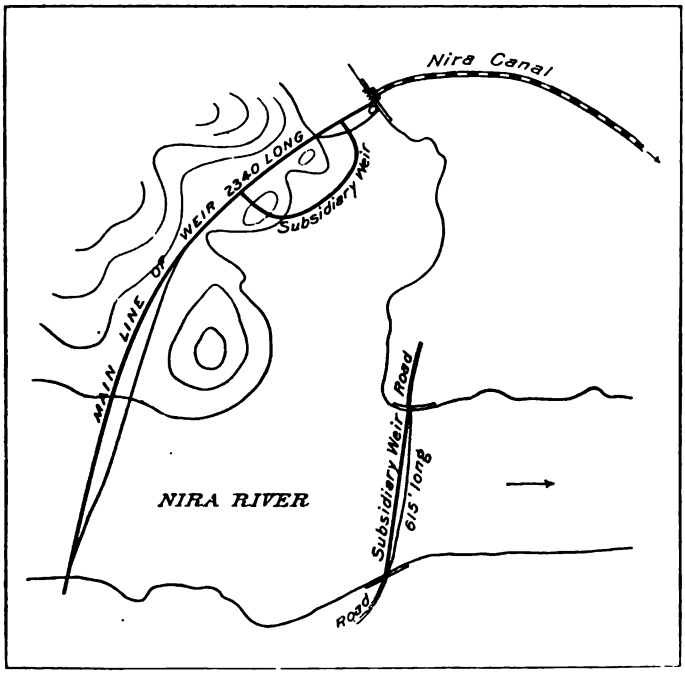


FIG. 44.—Plan of head-works, Nira canal, Vir.

way. When the water ceases to enter the boxes, owing to its having fallen below the level of the inlets, it soon runs out from holes at the bottom and the counterweights then become heavier than the gate and lift the latter. Giving the proper weight to these counterpoises is one of the important details of the apparatus.

The Nira canal heads at Vir, 19¼ miles below the reservoir (Pl. XX, *A*). The river bed between these two points being of a rocky character little or no loss from absorption takes place. The pick-up or diversion weir is constructed across the Nira River at its junction with the River Vir, and it crosses both of these streams and the point of land between them (fig. 44). The total length of the weir is 2,340

feet, and its greatest height above the foundation is 43½ dam is constructed of uncoursed rubble masonry and is 9 f top (fig. 45). The rear slopes are 8 feet on 1 for 20 feet, for the remainder or lower part. The upstream face ha batter of 20 on 1. At no place is the mean thickness les the weight of the dam. The main weir consists of two st tions connected by a curved wall over which the water wi This wall extends through the point of land connecting the and a channel 126 feet in width is excavated below it, con rivers. The weir is founded on solid rock throughout, bu water cushion and break the force of the great flood which

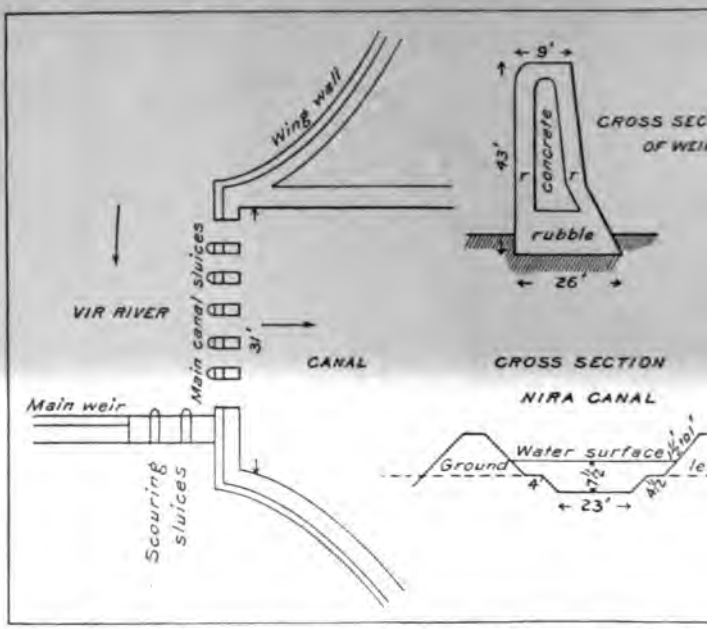


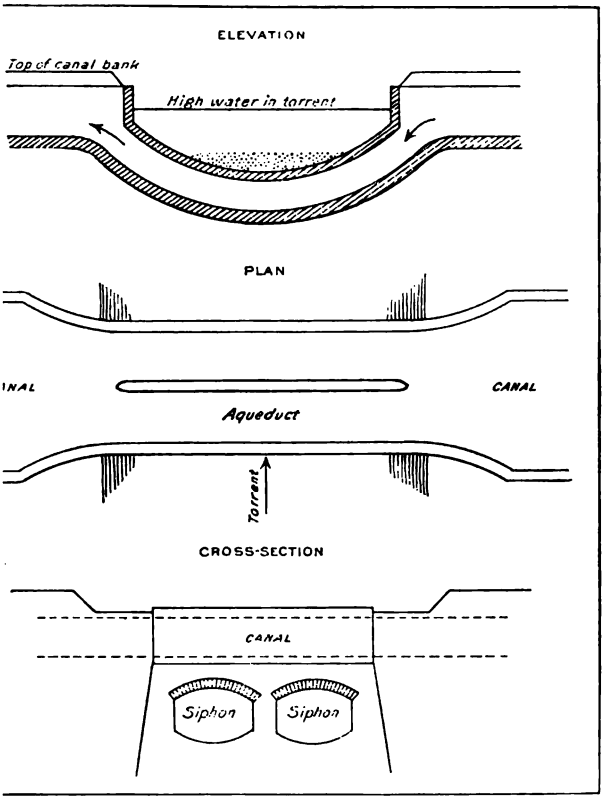
FIG. 45.—Plan of regulator head and cross-section of weir and canal banks,

it, a subsidiary weir, situated 2,800 feet below the main vided. The total length of this subsidiary weir is 615 fe 24½ feet high, with its crest 20 feet lower than that of the It thus forms a permanent water cushion 20 feet deep bel weir. Like the main weir, this subsidiary weir is constr best uncoursed rubble masonry, and has a roadway on t a maximum flood, it is estimated that the cushion will be when the overfall will be only 8 feet deep.

The catchment basin above this diversion weir is 700 s and the greatest flood estimated to pass over it is 158,000 corresponding to a run off of nearly half an inch per greatest flood which has occurred rose 8 feet over the crest weir and 13 feet in depth over that of the subsidiary wei

MAIN CANAL AND SUBSIDIARY WEIRS, NIRA SYSTEM. VIR IN GREAT FLOOD.

.r backs the water up the Nira River a distance of 12 val and impounds about 1,400 acre-feet, or sufficient to ve supply for the canal for a few days. It is expected, ; this basin will silt up in the course of time. The canal ıe left bank of the river at right angles to the River Vir in a portion of the weir just below this head it has been ary to construct a second subsidiary weir of trifling which catches the direct flood from the Vir on a water XX, *A*).



ı. 46.—Nira canal: superpassage at siphon for Jewhar Torrent.

after leaving the head-gates makes a long sweep through curving until it is parallel to the river. In the cut ridge, which is 400 feet in length, the average depth of 50 feet. The velocity in the canal averages 1.8 feet per regulating sluices (fig. 45) at the canal head are 7 in ı 4 feet wide and have an available head of 9 inches. In ıcent to the head regulators are a set of two scouring ı have not a sufficient area to remove silt which may which act as all other scouring sluices in keeping open a

clear channel past the head of the canal. At its head the bott of the canal is 23 feet, the depth of water 7½ feet, and the ordinarily 470 second-feet, while the fall is 6 inches per mil present constructed the main canal is 103 miles long and co irrigable area of 300 square miles. There have been constr miles of distributaries commanding a portion of this area. of the canal increases to 3 feet in a mile in rock cuts with a co ing cross-sectional area. In earth where the canal cross small the greatest fall is 18 inches in a mile. The accou fig. 45 is a cross section of the canal showing the way in w berms and banks are formed.

Numerous cross drainages are passed in the line of the c largest works being aqueducts over the Kurra River and the and a superpassage over the Jewhar Torrent. The Kurra (Pl. XX, *B*) consists of 20 arches of 30 feet span each. The of the river is estimated to touch the crowns of the arches at of 9 feet per second through them. The superpassage for th Torrent is novel (fig. 46) and has an advantage over weirs, a ing of the canal is avoided. This structure differs from an superpassage in being in solid rock, thus acting as a weir; a canal being carried under without any great drop or fall. clears the arching to avoid loss of velocity; in this it di siphons. There is extra velocity and consequent narrowi waterway. Regarding the aqueducts, it may be observed the superpassages, the object has been to make them as possible without sacrificing too much fall, and the narrowe is smoothly paved and grouted. It is estimated that the ac along this steep incline, together with the original velocity of gives the requisite speed before the water enters the aque inclination is given along the aqueduct sufficient to mai velocity and carry the water across, but directly the passage the canal is gradually widened and gets its regular fall per

The total outlay on the Nira project to the end of the yea as follows:

Total outlay on Nira project to end of 1888.

Canals, distributaries, etc	
Bhatgur reservoir (uncompleted)	
Twenty-three sluice gates and the subsidiary weir	
Canal head-works at Vir	
Nineteen aqueducts	
Two siphon superpassages	
Seventy-five small weirs	
Hydrants, turbines, etc	
Compensation for land	
Total, including sundry others	

To the close of 1901 the expenses, exclusive of the Bhat voir were: For main canals, $630,000; distributaries, $68,

works, $706,000; establishment, $342,000; tools and plant, $41,000; total, $1,787,000. The revenues to end of 1901 had been: Water rates, $362,000; plantations, $3,000; rent of buildings, $1,600; total, including miscellaneous, $367,000.

BETWA PROJECT.

The first proposal for the construction of a canal from the Betwa River was made by Major-General Strachey in November, 1855. The question was again considered after the mutiny in 1859, but nothing was done until 1867, when Lieutenant Home, R. E., was directed to conduct the inquiry.

Lieutenant Home made examinations in 1867 and 1868, and submitted a preliminary report which showed that it was practicable to utilize the waters of the Betwa River for irrigating a tract in Bundelcund, in the Northwest Provinces, lying between the Rivers Jumna, Pahuj, and Betwa, whereupon more complete investigations were ordered. The examination was continued by Lieutenant Bagge and estimate submitted. Further examinations were made later, in 1869, by Mr. Anderson, under the general direction of Colonel Greathed, chief engineer, and the conclusions arrived at by him were that Parichi was the best position for a diversion weir; that for four or five months of the year 1,000 second-feet could be depended on even during years of minimum rainfall, but that final further examination was advisable. In November of the same year Lieutenant Bagge submitted a detailed project and estimate of the Betwa canal, including a provision for water storage. The estimates were so high that the project was shelved, especially as there was no prospect of the enterprise realizing more than from 3½ to 4 per cent interest on the expenditure. Finally, in November, 1873, the Government sanctioned the estimates, restricting the canal to wet-weather irrigation without provision for navigation and without being supplemented by storage.

The works of the canal were designed and carried out under these general plans, but were afterwards modified so as to include a storage reservoir and irrigation throughout the year. Various sites were discussed for the location of the storage works, that at Khoord being the most favorably considered for some time, but finally Paricha, a site previously decided upon for the diversion weir, was accepted as the best location.

The area covered by the Betwa canal system is about 1,500 square miles. The surface formation of the bench land covered is very peculiar. The highlands border on the valleys of the Pahuj and Betwa rivers, while the lowlands occupy the central part, being drained by two separate channels which unite as they approach the River Jumna. Owing to the irregularity of the rainfall and the excessive fertility of the soil on this area of land, it is difficult to make a canal project remunerative without supplementing its perennial discharge with

storage water, since during the ordinary season of the year, when the river flows an abundant stream of water, the rainfall on the irrigated area is sufficient for most of the needs of the agriculturist. The site chosen for the diversion weir is an excellent one, the unusual width of the river bed at this point affording an ample wasteway for the great floods which may be expected during certain periods. It was necessary to design the storage dam as an overfall weir throughout its entire length, as the maximum flood to be discharged amounts to 750,000 second-feet. A rocky barrier or ledge runs across the bed of the river at this point and forms an excellent foundation for the weir. The river has a straight run between good stiff banks, and there is a plentiful supply of good building stone in the neighborhood.

For the first 20 miles the canal runs in a direct line, and is in an excavation varying in depth from 5 to 40 feet. This portion of the line is fortunately in earth and may be considered as purely diversion line, being too deep for purposes of flow irrigation. The first 6 miles of the canal are protected by a drainage channel parallel to it, which catches the discharge from the various small streams crossing it at right angles to the direction of the canal. Through this first portion of its length the cross section of the canal is 20 feet at the bottom with a depth of 12 feet of water. The first 3 miles below the head are revetted both on the banks and the bed of the canal. This revetment consists of a paving of loose stones carefully laid by hand. No silting of any importance takes place in the canal, as the water is admitted to it only during the season of moderate discharge in the river, and as it is taken from the storage reservoir most of the sediment has been previously deposited. The growth of weeds, however, is rather excessive, owing to the low slope of the canal, and the latter is periodically closed in order that the weeds may be cleared by hand.

One of the principal branches—the Hamirpur branch—is designed with a bottom width of 15 feet for the first 30 miles and a depth of water at head of 6 feet, its slope being 1 in 3,000, which gives a velocity of 1¾ feet per second and a discharge of 340 second-feet. From this point on, the branch diminishes gradually in dimensions and carrying capacity, the slope being continually altered so as to give an average velocity throughout of about 3 feet per second. Another main branch, called the Kathund branch, has a bed of 30 feet and a depth of 6 feet, and is designed to carry 500 second-feet of water.[a]

The local drainage met in the first few miles is disposed of by means of a parallel drainage canal having an inlet into the canal, and by another channel near the canal head discharging into the Betwa River. There are two drainage siphons, one in the seventeenth mile and one on the Hamipur branch. The siphon on the main canal will discharge 1,300 second-feet and is provided with five vents of 30 square feet, which head the water up 1¼ feet and discharge it with a velocity of 8¼

[a] The Betwa Canal Project in the Northwest Provinces, Records of the Government of India, Calcutta, 1877.

ɔer second. The falls along the lines of the canal and the bridges f the usual pattern described elsewhere.

e minimum discharge of the river may be taken as about 50 ıd-feet, while the maximum discharge may be as great as 750,000 ıd-feet. The average rainfall over the irrigated lands is 39 inches. gross area of land commanded is 522,800 acres and the culturable is 348,586 acres, while the area irrigated at present is 180,000 ı. The expenditure on the works, including all charges to the 1893, was $1,435,000. These works include 19 miles of main l, 163 miles of branch canals, and 380 miles of distributaries. duty performed in 1887 during the fall crop was 67 acres per ıd-foot of the discharge at the head, or 76 acres per second-foot

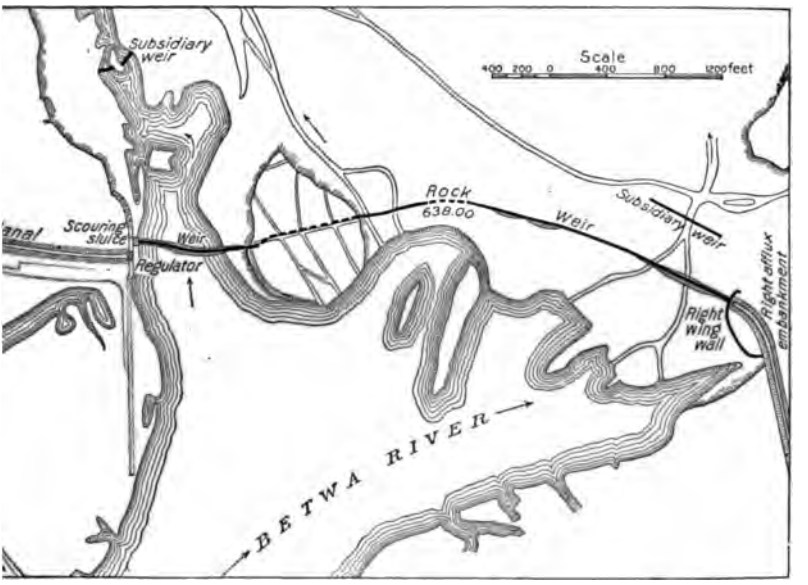


FIG. 47.—Betwa project; plan of dam and head-works.

ıe discharge utilized. The principal crops raised were wheat and ɜy, with a small amount of pulses, indigo, and opium.

ıe weir alignment has been skillfully located so as to make the ; of the rocky barrier which crosses the river at the point where constructed (fig. 47). The weir is placed on the ridge of this which curves away from the left flank and is convex upstream, ıat the water will be thrown toward the middle of the channel. height of the weir above the river bed varies between 0.4 of a and 60 feet, except on the left bank, where the rock was higher the sill and had to be cut down. The total length between the ɜ on either protected bank is 3,296 feet and it is calculated to pro- ; an afflux in extreme flood of 6.5. The cross section of the weir t first proposed is a trapezoid with sides of equal slope, viz, 10

horizontal to 25½ vertical, the top width being 10½ feet
engineer, Colonel Greathed, did not approve of this cross
decided that the downstream face of the weir should be n
in order that a 6-inch film of water passing over the we
clear of the toe, and in order to increase the stability o
has been extended upstream somewhat. The upstream e
rounded in order that driftwood may pass over without
and injury to the masonry, and a curve has been given to
face, instead of a batter, in order to facilitate the pass
and drift.

The accompanying section of the weir (fig. 48) is fo
part. Fifteen feet has been adopted as a convenient
width for the top, which is coped with ashlar 18 inches thi
blocks being not less than 15 inches wide and weighing abo

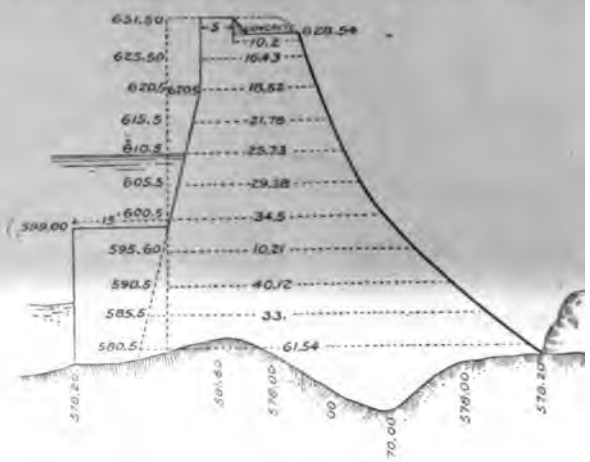


FIG. 48. Cross section of Betwa weir.

The body of the weir is built of rubble masonry coursed o
the minimum dimensions of the stones being 9 inches lo
wide, and 6 inches high, with a due proportion of bond s
ashlar is set in Portland cement and the rubble in nativ
lime cement. The body of the weir appears to be unnece
and heavy; especially is this true of the great block of ma
is placed at the toe. The cross section, however, was c
the engineers to be necessary, owing to the steepness of
the river and the magnitude of the floods which it discha

As shown by the accompanying plan of the river and
crossing it (fig. 47), the latter is constructed in three diffe
separated by a large island, on which it abuts in one pla
rock which projects above the surface of the water in ar
The deepest portion of the channel is adjacent to the le
the greatest height of the weir at this point, including fo

newhat over 60 feet. At the toe of the weir on the downstream slope built out a great block of masonry from 15 to 16 feet in width, which intended to receive a portion of the jar caused by the impact of the ed water passing over the weir. Adjacent to the left bank a row of dersluices, four in number, are constructed in the weir itself, the ject of which is to give a scour past the canal head, thus keeping e latter free of silt. The canal itself heads just above these underices, the regulator consisting of five openings, arranged with a double er of gates, one above the other, in such manner that either the upper

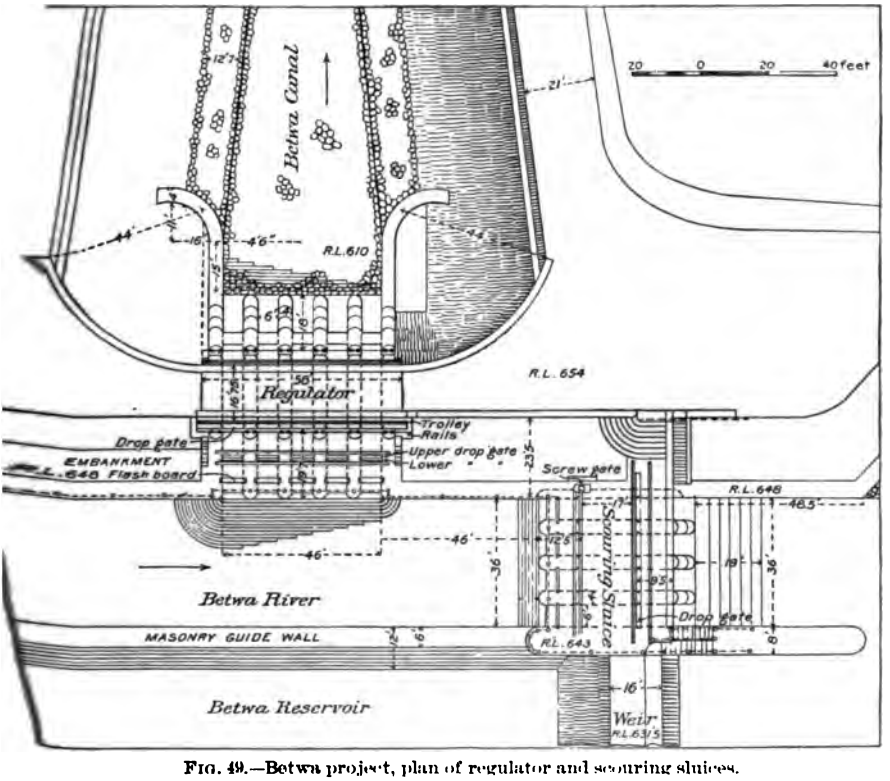


FIG. 49.—Betwa project, plan of regulator and scouring sluices.

or lower series may be used at will according to the depth of water in the reservoir.

Below the portion of the weir across the main channel is constructed a subsidiary weir at a distance of perhaps 1,400 feet, the object of which is to back the water up against the main weir, thus producing a water cushion on which the floods shall fall. The extreme height of this subsidiary weir is about 18 feet and the height of overfall from the main weir to the water cushion formed by it is 21½ feet, though in time of flood this will be reduced to 8 feet. The top width of the subsidiary weir is 12 feet, and its walls are nearly

vertical on the downstream side with a slope of about 10 on 1 upstream. The main body of the weir between the island and the narrow right-bank channel is very low and the overfall is onto a solid rock bed. It was accordingly not necessary to construct a subsidiary weir below this portion of the weir, but across the right-bank channel, where the height of the weir nearly approaches that at the extreme left bank, a secondary subsidiary weir has been constructed at a distance of about 200 feet below the main weir, and with the same object and same crest level as the subsidiary weir just described.

The available net storage depth of the reservoir is 21½ feet, and its capacity above the canal bed is 36,800 acre-feet, though it has been found that the lower 6 feet of depth is of little service, as the head above is not enough to force the water into the canal with sufficient freedom to make it practically available.

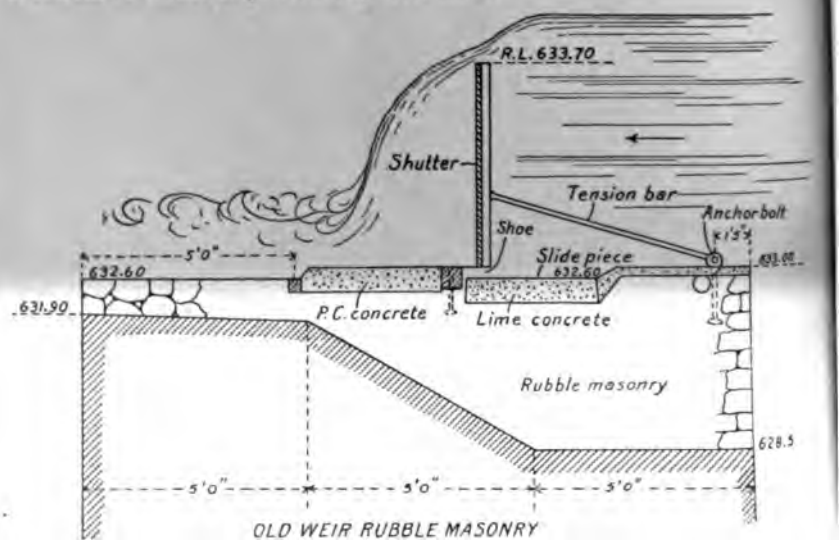


FIG. 50.—Automatic drop shutters, Betwa dam.

In 1897 the subject of increasing the storage capacity of this dam by adding automatic drop shutters on its crest was considered, and the plans for carrying out this work were finally approved and carried to completion in 1901. These works consist of two parts, namely, the building up of the weir crest by the addition of 1 foot in height of the best rubble masonry, and of shutters 6 feet high placed on top o these, thus making the total increase in height to which the wate can be raised amount to 7 feet (fig. 50). By this means the gros increase in storage capacity of the reservoir with the shutters raise was 1,800 acre-feet, which is equivalent to an additional nine day flood supply of the canal.

The shutters are illustrative of the latest Indian practice in th design of automatic drop gates. Moreover, they were subjected t the unusual test on completion, in 1902, in the form of an extraor

[illegible]ary flood of 970,000 second-feet volume instead of the greatest maxi[illegible]m anticipated, of 750,000 second-feet. This flood passed over the [illegible]st of the dam to a maximum height of 16.4 feet, when it had been [illegible]igned only to stand a previous known flood height of 6.5. For[illegible]ately, the shutters worked successfully and rapidly, and neither [illegible]r nor shutters sustained any material injury. These shutters are [illegible]h 6 feet high and 12 feet long, and as the length of the weir crest [illegible] 3,600 feet there are 300 such shutters. They are made entirely of

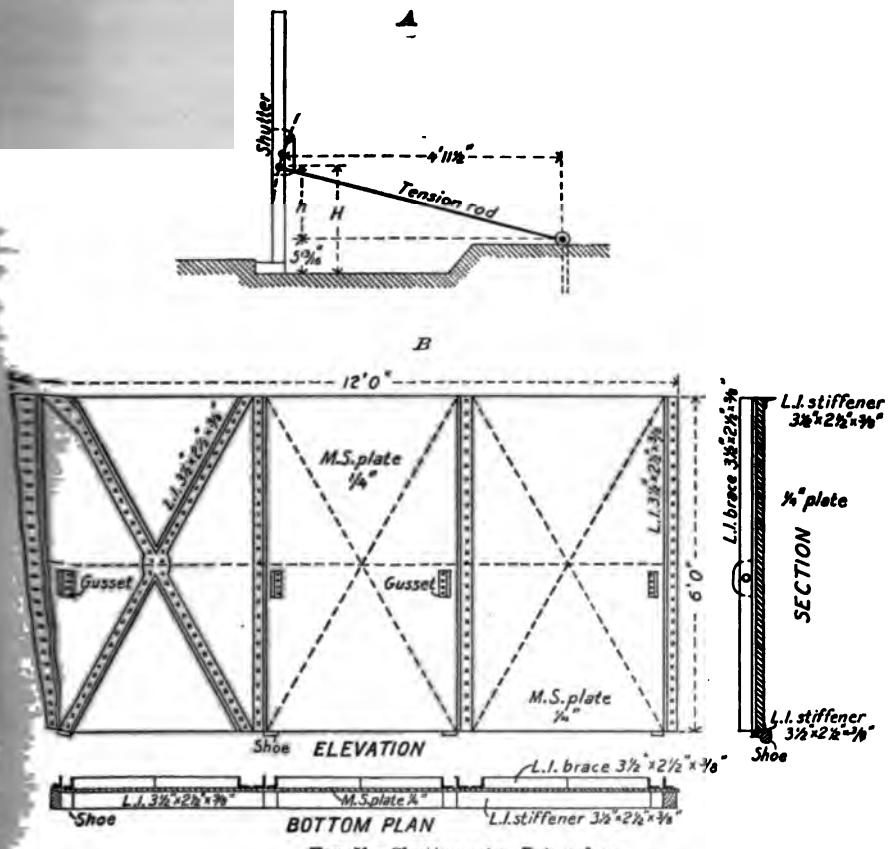


FIG. 51.—Shutter gates, Betwa dam.

steel, consisting of two one-fourth inch plates joined along their middle and stiffened both longitudinally and laterally by angle iron 3½ by 2½ by ⅜ inches (fig. 51). To the flanges of the vertical stiffeners are pivoted 1¾-inch tension bars. The other end is similarly attached to anchor bolts built 2 feet into the masonry crest of the weir. There are four such tension bars to each 12-foot gate. The point of attachment of the tension bar and shutter is so designed that the gates fall automatically with a given depth of water passing over them, thus securing safety in case of excessive floods. The bottom of each gate

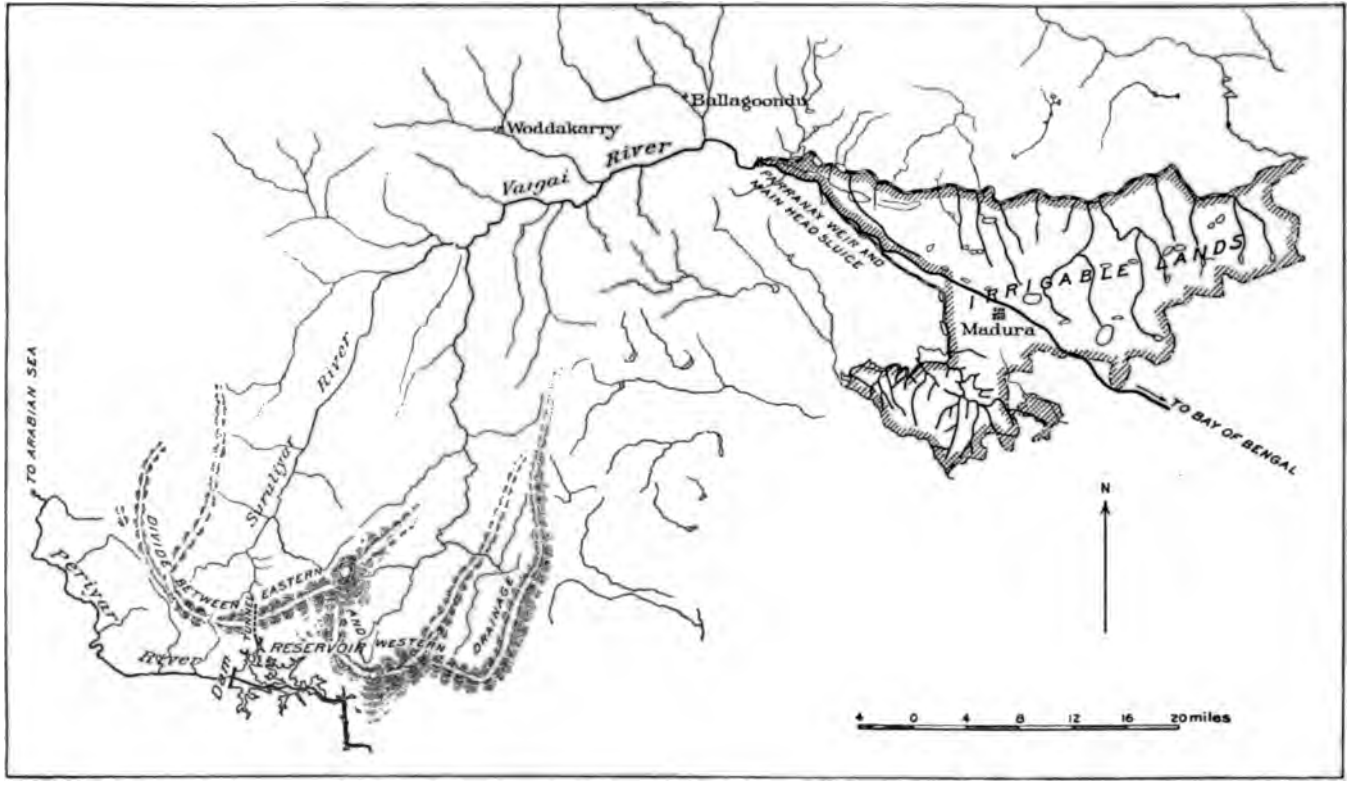
is supplied with four steel shoes which rest upon sliding plates built into the weir crest, thus reducing the frictional resistance when the gates fall (fig. 51). Wooden boulks, 4 feet by 4 inches, are fixed to the ends of the shutters, which have a space of 1 foot separating them, which is calked when the gates are raised.

If the 300 shutters were to fall together, the shock would unduly strain the weir and the flood volume submerge the river banks below. Hence the attachment of the tension bars has been so arranged that each third gate falls under different depths of water. The first third fall with a depth over top of 2 feet, the next with 3 feet, and the last with 4 feet. Thus after the first third fall the released water reduces the flood depth, and the latter must increase considerably to top the second third, and so on. It was not anticipated that all the shutters would ever fall, yet this occurred in the flood above mentioned.

Careful calculations were necessary to determine the point of attachment for each group of shutters, and as a fraction of an inch would make a great difference in upsetting the gate careful experiments were made with a model gate to determine the exact point of attachment of the tension rods. So as to have uniformity of length of the latter, the pivot holes in the shutters were arranged in an arc of circle at the required height from the bottom of the shoe (fig. 51, *A*).

Hole.	H.		Depth required to upset.
	Ft.	*in.*	*Feet.*
1	2	$0\frac{3}{4}$	2
2	2	$1\frac{3}{4}$	3
3	2	$2\frac{3}{4}$	4

The undersluices which are constructed in the main body of the weir opposite the canal head are placed at right angles with the face of the canal regulator in order to give sufficient scour along the canal head to prevent the deposit of silt. The height of the face wall is given a margin of 6 feet above the calculated afflux level. The undersluices consist of four vents, the bottoms of which are on a level with the sill of the canal and are each $16\frac{1}{2}$ by $16\frac{2}{3}$ feet in dimensions. The piers of the undersluices are 5 feet thick in order to support the great superincumbent weight of masonry. The abutments, piers, arches, cut-waters, etc., are of ashlar, the rest of the work being of rubble masonry, the upstream face being pointed with Portland cement. A peculiar curve is given to the upper face of the piers between the sluice vents, forming a venar-contractor in such manner as to pass the water with the least friction through the sluiceways. The sluices are each closed by a series of two plain drop gates, the upstream set of gates being operated by a screw by means of hand levers from above.



PLAN OF PERIYAR PROJECT, MADRAS.

the lower openings being closed by slash boards let into grooves in the piers.

The gates of the regulating sluices of the canal are of such cross-sectional area as to admit 1,000 second-feet of water. The number of openings in the regulator is five, each 6 feet in width by 5 feet in height, and, as before stated, are two decks in height, being closed by separate gates in such manner that either the upper or lower series of gates may be opened at will, according to the depth and pressure of water in the reservoir. Below the main regulator gates, which are operated by screws by means of hand levers worked from above, are a set of two safety drop gates, which are raised by means of a traveling winch. The accompanying drawings (fig. 49) illustrate some of the details of construction of the regulating and flushing sluices. These regulating gates, like those of the flushing sluices, are constructed of the best rubble masonry, finished with ashlar. The total cost of the head gates and flushing sluices was $100,000, while the main weir, inclusive of the subsidiary weirs, cost only $160,000.

The left flank of the river is protected up and down stream by a wing wall, the former 140 feet long and the latter 75 feet long. The whole length of the wing walls is founded on rock, and, excepting the parapet, they are constructed chiefly of rubble masonry. In order to avoid inundation by the afflux caused by the weir, embankments have been constructed on both sides of the river. The top width of these is 20 feet and the center of each is hearted with a puddle wall 3 feet thick.

The Betwa project was sanctioned as a protective work. The total expenditure on it up to the end of 1901 was $1,500,000, the total revenues from irrigation were $9,300, and the total working expenses were $30,000; while the net revenue account showed a deficit over all receipts, including those from irrigation, of $20,000. This work has been in operation but a few years and the revenue has been constantly increasing in amount relative to the working expenses.

PERIYAR PROJECT.

The Periyar project for the irrigation of the Vaigai Valley, in Madras Presidency, is probably the most interesting illustration of the combined storage work and irrigation canal system to be found in India, especially as it was sanctioned as a protective work. The project (Pl. XXII) includes the construction of a dam to close the valley of the Periyar River to store 300,000 acre-feet of water, of which 150,000 acre-feet are above the sill of the outlet tunnel and are thus available for irrigation; the construction of a tunnel through the watershed dividing the valley of the Periyar from that of the Vaigai River for the purpose of drawing off the water from the reservoir, with the necessary sluices and subsidiary works for controlling the passage of the supply of the Periyar down the valley of the tributary

alled the Sooroolly, by which it reaches the Vaigai; and finally, the onstruction of the works necessary for the regulation and distribution of this supply for the command of 107,650 acres of land in the Vaigai Valley, of which 76,445 acres were irrigated in 1898–99. As he waters of the Periyar flow westward into the Arabian Sea, they re thus diverted across the peninsular divide, the Ghauts, to the eastern coast of India, where they enter the Bay of Bengal.

The area of country which is irrigated by this project was described y Major Ryves, R. E., in his early report on the project in 1867, as eing about 1,200 square miles in extent, with a population of nearly alf a million. Up to the present time irrigation has been practiced rom native tanks, most of which, however, have become very shallow, and from which the waste of water by evaporation is at least 30 per cent. In very good years the water supply from the Vaigai itself is sufficient to irrigate 20,000 acres. Agricultural operations in this region are rarely rewarded by a good crop, although the land where water can be provided is of the most fertile character. During the famine of 1876 as much as $600,000 was expended in relief in this district.

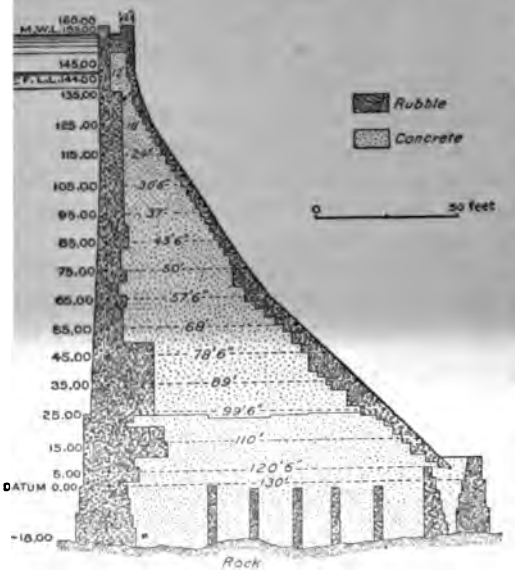


FIG. 52.—Cross section Periyar dam.

The idea of utilizing the water of the Periyar for the irrigation of the Vaigai is an old one. It was first reported in 1808 by Sir James Caldwell, who condemned the project as decidedly chimerical and unworthy of further regard. The subject was occasionally discussed from time to time, but it was not until 1867 that it was practically brought forward by Major Ryves. Major Ryves's proposals included an earth dam 162 feet high, with an escape crest 142 feet above the river bed, and the water was to be diverted into the Vaigai Valley by a cutting having a maximum depth through the watershed of 52 feet. Other examinations were made, and finally a project was submitted by Mr. Smith in 1872, which included a dam 171 feet in height, to be constructed by the silting process and having an escape of 400 feet in length blasted out of the saddle at the right bank.

The final project, and that which has been adopted, was the outc

PERIYAR DAM DURING CONSTRUCTION.

come of further examinations made by Mr. Smith and Major Pennycuick, though to the latter are due most of the later details, and under him is being conducted the construction of the works. It was in this report that Major Pennycuick submitted the first proposals for the substitution of a masonry dam for one of earth. These final proposals were submitted in 1882, and included the construction of a dam (fig. 52), located at the same point as that chosen by Mr. Smith, 7 miles below Major Ryves's site, the height to be 155 feet above the bed of the river, and the summit surmounted by a parapet 5 feet high and 4 thick. The dam proper is 12 feet thick at the top and 114¾ feet at the lowest part. It is constructed throughout of concrete composed of 25 parts of hydraulic lime, 30 of sand, and 100 of broken stone. The front face is covered with a plaster composed of equal parts of lime

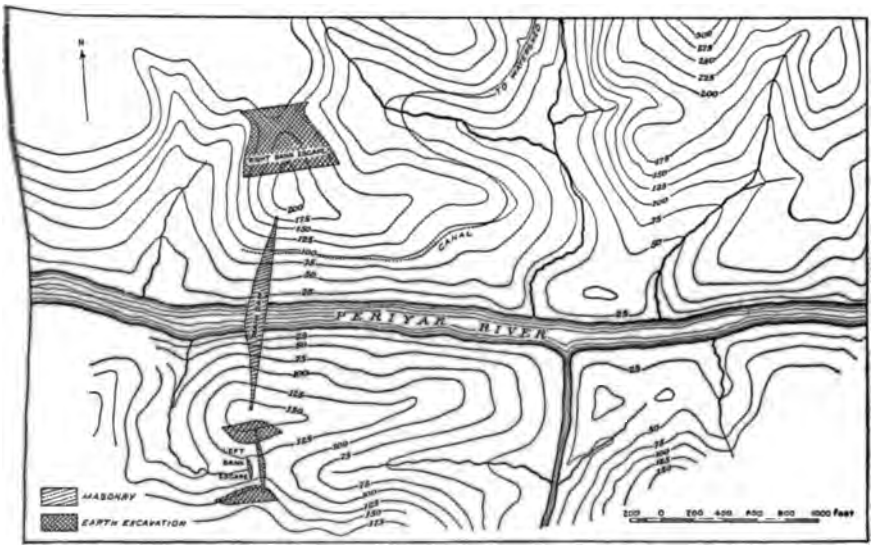


FIG. 53.—Periyar head-works, plan of dam and escape.

and sand. A temporary dam 30 feet in maximum height was constructed above the main dam and a similar dam 10 feet high below the main site, in order to enable the latter to be completely cleared and the foundation trenches blasted out before the main dam was begun.

For the formation of wasteways two saddles are utilized, one on each bank (fig. 53). The one on the right bank has solid rock at a minimum level of 154 feet above the river bed, and will be cut down for a length of 420 feet to a level of 144 feet. On the left bank the solid rock is at a level of 104 feet, and the saddle will be built across with similar material to that of the main dam to the same level, 144 feet. The wall thus formed has a length on its crest of 403 feet and a further length of 97 feet in excavation, making 500 feet in all. The aggregate length of the two wasteways is thus 920 feet. At a distance of 60 feet from the escape wall on the left bank is built a sub-

sidiary weir 10 feet in height, with its crest 30 feet below the upper wall, thus forming a water cushion. In the side of the valley tributary of the Periyar, just above the dam, a cutting was started at a height of 113 feet above the river bed running down toward the watershed, 21 feet wide at bottom, with a fall of 1 in 440. The depth of the cutting in rock is 50 feet at a distance of 5,400 feet from the starting point, where it is replaced by a tunnel with an area of 80 square feet and a fall of 1 in 75. At its lower end the tunnel will communicate with the bed of a small stream by a cutting similar to that at the south end, 160 feet in length, the total length of the tunnel being 6,650 feet.

The rock in the river bed and on the watershed ridge is a hard syenite free from fissures and suitable both for a foundation for the dam and for material for its construction. Most modern dams of any magnitude have been built of uncoursed rubble masonry. Major Pennycuick argues that "concrete is nothing more than uncoursed rubble masonry reduced to its simplest form." As regards resistance to crushing or to percolation the value of the two materials is identical; he further says, "unless it be considered as a point in favor of concrete that it must be solid, while rubble may, if the supervision be defective, contain void spaces not filled with mortar. The selection depends entirely upon their relative cost, the quantities of materials in both being practically identical." At the site of the Periyar works skilled labor is abnormally expensive and difficult to procure, while the facilities for the use of labor-saving machinery which can be largely used in the manufacture of concrete are unusually great. Accordingly, after full discussion, it was decided to adopt concrete as the material for the construction of the dam. Excellent sand is procurable from the bed of the river in numerous places above the dam.

The section of the escape dam (fig. 52) on the left bank is designed so that the lines of pressure shall be within the middle third when a depth of 12 feet of water is passing over its crest, and so that the water shall have a clear fall to the surface of the water cushion below. As before stated, at a distance of 60 feet from the upper escape dam is constructed another dam 10 feet in height, with its crest 30 feet below that of the former. The depth of water passing over this dam will be about one and one-half that passing over the upper one, so that the fall from surface to surface will vary from 24 to 30 feet, and the depth of water cushion from 10 to 28 feet. The length of the right bank wasteway is fixed by the quantity of stone required for the dam. This quantity is 3,600,000 cubic feet, of which 1,400,000 are brought from the watershed cuttings, the cost of conveyance being less than that of quarrying at the dam site. The balance after the material has been supplied from other convenient sources is 1,600,000 cubic feet, to be obtained from the right bank waste way. It is contemplated that a great flood will raise the water to a level of 153.1 feet, while it would take several times this discharge to raise it to 155 feet. The maximum

ood recorded occurred in 1869, and amounted to 65,500 second-feet; eing 131,200 acre-feet in twenty-four hours, and 7,100 acre-feet in n hour.

From the mouth of the watershed tunnel the water of the Periyar passes by minor tributaries into the Sooroolly River (Pl. XXII), and is controlled by numerous regulating works along the course of the various tributaries of the Vaigai. These works consist chiefly of sluices of simple form, their object being to pass the Periyar water around the different weirs which have been constructed by the natives or Government in past times for the utilization of the water of the local drainage basin. None of these old works are provided with head-sluices. Accordingly, the regulating sluiceways which are planned in connection with the Periyar project are designed to discharge the maximum amount of water which that project will furnish when the surface level of the stream above each weir is flush with the bed of the existing channel.

In 1898 a Stoney patent free-roller gate was erected at the tunnel head to replace the equilibrium shutters which were found unworkable. It works in a cast-iron frame built in a masonry sluice chamber 15½ by 15 feet in plan, the sill being 49½ feet below the top of the platform and 37 feet 3 inches below the full lake level. The gate is 12 feet 9 inches high and 9 feet 6 inches wide and is supported on 20 pairs of cast-iron rollers. It is of ⅜-inch steel plate, suitably braced, is worked by a screw-lifting gear and winch and is balanced by a counterweight to two-thirds its weight.

From the mouth of the tunnel to the junction of the Sooroolly with the Vaigai is about 46 miles, and for a further distance of 40 miles the water is conveyed by the latter river, no works being required in connection with it until it reaches the Peranny, at which point the distributive works begin. The Peranny weir is a substantial structure already existing and requiring but little improvement, the only alterations made being the closing of the undersluices, the leveling of the crest 5 feet above the floor of the latter, and some slight additions to the wing walls, apron, etc. Two main distributive canals have been planned, passing close under the foothills surrounding the plains about Madura. These and their branches all terminate in natural drainage channels. The quantity of water designed to be carried by the southern main canal is 1,500 second-feet at its head, where the depth is 6 feet, and it is designed to irrigate 75,000 acres of land. The existing or northern main canal is to have a head-sluice of 20 vents, all of 5½ feet span. The steepness of the Vaigai Valley necessitates the construction of numerous drops or falls in both the main and branch channels. For the passage of cross drainage there are in all 26 inlets and 32 level escape outlets on the main canal, besides 2 aqueducts and 6 culverts, 3 inverted siphons, and other works. The head and regulating works for the main canal and a secondary channel called the

Vedacunay channel, are only 1,460 feet apart. It is necessary, however, that both works be built, for the ground between the two is unfavorable for an open channel. There 36 miles of main canals and 164 miles of distributaries.

The water supply is derived from the Periyar, the drainage area of which is 300 square miles, and is undoubtedly sufficient. The estimated rainfall in the Periyar Valley varies between 65 and 200 inches

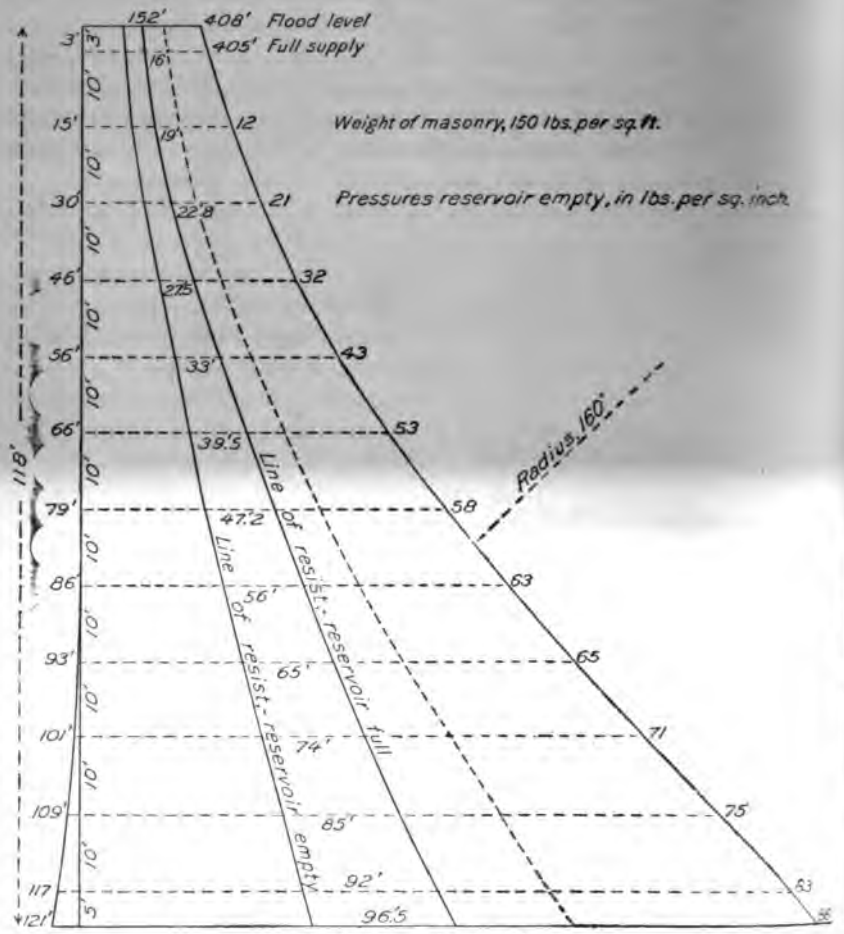


FIG. 54.—Tansa dam, Bombay.

per annum and averages 125 inches, while the depth of run-off from the catchment basin is 49 inches. The estimated discharge of the river available for storage is 760,000 acre-feet, while the loss by evaporation in Periyar Lake and in the beds of the Sooroolly and Vaigai rivers is 70,000 acre-feet, leaving a balance available for irrigation of 680,000 acre-feet. The amount of water required for the irrigation of the lands in the Vaigai Valley is 600,000 acre-feet. It is estimated that

A. FOUNDATION, TANSA DAM.

B. CARRYING STONES TO BUILD TANSA DAM.

not over 7,500 acre-feet will be required to fill the beds of the rivers down which the waters of the Periyar will be passed.

While the maximum storage capacity of the Periyar reservoir is estimated at 300,000 acre-feet, the total available storage capacity above the sills of the discharge sluices is but 150,000 acre-feet. It was estimated that the total cost of this work, including the latest additions to the project and interest charges, would amount to $2,894,000, and this sum has been expended. The works were completed within six years from the time when they were commenced, and the irrigation was expected to be fully developed within ten years after their completion. The gross revenues are estimated to be $350,000 and the working expenses and collection charges $62,000. In 1898–99 the gross revenue was $157,000, the working expenses $49,000, and the net revenue $108,000.

TANSA RESERVOIR.

This reservoir is designed not for irrigation, but for supplying water to the city of Bombay for domestic uses. It is, however, constructed upon the general principles involved in water storage for purposes of

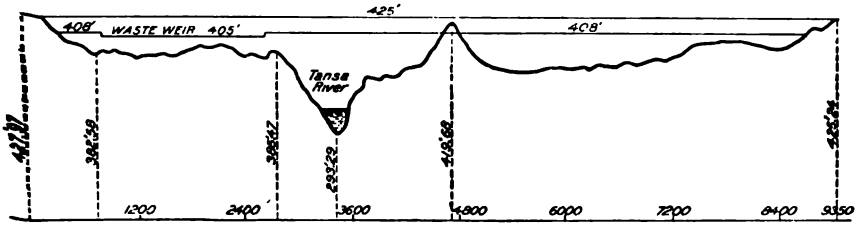


FIG. 55.—Tansa project, longitudinal section of dam.

irrigation, and the dam which forms it is of such great size and excellent workmanship and design that a description of it here will at least be instructive. The project for the construction of the great reservoir on the Tansa River for the storage of water for the supply of the city of Bombay was first brought prominently forward by Maj. Hector Tullock about 1870. The plans of the reservoir and dam as at present constructed were worked out and the construction undertaken by Mr. W. Clerke, chief engineer of the water supply of Bombay.

The Tansa River heads near the summit of the Western Ghauts, where the rainfall is great, ranging from 150 to 200 inches per annum. The area of the catchment basin above the dam site is but 52½ square miles, but the slopes are so steep and the precipitation so great in amount that the discharge is estimated to be about 8,000,000 cubic feet per day. The area of the reservoir is 5.5 square miles, at full supply level 405 feet elevation, and the maximum available depth of water above the sills of the discharge sluices is 20 feet. Its net available capacity is 59,000 acre-feet, less 18,000 acre-feet, which is equivalent to a loss of 6 feet in depth by evaporation and absorption

leaving 41,000 acre-feet. The gross storage capacity of this re is far greater than the figures given above, and much more could be utilized if it were needed for purposes of irrigation by off the discharge sluices at a lower elevation.

The dam (figs. 54 and 55) is constructed of the best uncours ble masonry, laid in hydraulic mortar, which is made near t site. The total length of its crest is now 8,800 feet, but may be 9,350 feet, of which 1,650 feet are utilized as a wasteway south end of the dam. It is constructed in two tangents in manner as to get the shortest line on a bed-rock foundation. tangents meet near the center of the dam in a sharp rocky which projects a little above its crest. The top of the wastew feet below the maximum flood height of the dam, and the vol flood which will have to be wasted is estimated to be 25,000 feet.

The total cost of this work was about as follows:

Cost of Tansa reservoir.

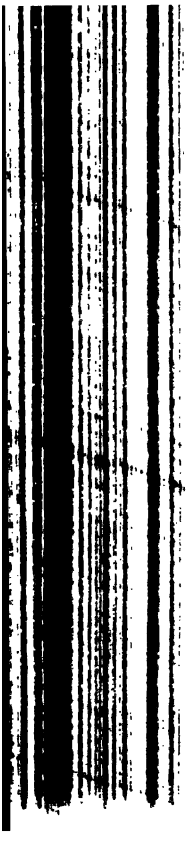
Compensation for land, etc.	
Excavations for foundations, 4,000,000 cubic feet, at 30 cents per cubic yard	
Rubble for masonry for the dam, 10,000,000 cubic feet, at $3 per cubic yard	
Total	

MASONRY DAMS.

It may be generally said that all of the masonry dams cons by Indian engineers in recent times have been designed accor the most approved modern formulas and the material of whi have been constructed has been almost uniformly uncoursed masonry. The Tansa dam (Pl. XXV) is the most logical inst the use of uncoursed rubble masonry throughout without any c work either in the facing or coping, thus giving an almost geneous wall. Mr. W. Clerke, chief engineer of this work that the strains due to shrinkage and settlement in a dam th structed are uniform throughout its mass and have little or n to rupture it. Whereas in other dams, such as those at Betw Bhatgur, where a deep layer of coursed stones has been laid of the central core of uncoursed rubble or concrete, the homog of the whole may be destroyed, owing to unequal shrinkage or s thus diminishing the effective cross section of the dam by the a of the coursed facing.

The Periyar dam is the most logical example of a dam const throughout of concrete without any facing or other mate destroy the homogeneous character of the material of whic constructed. The great dam at Bhatgur is an example of

NATIVES BUILDING TANSA DAM, BOMBAY.



structure; all of the upper portion of this dam above the lines the limit of pressure exceeds 60 pounds per square inch is ucted of concrete faced with coursed rubble masonry. Below int where the limit of pressure of 60 pounds per square inch is d, the material used throughout is uncoursed rubble masonry, however, as is the upper portion, with coursed stones. In ng up this structure the coursed facing and the interior heart-concrete were run up simultaneously in layers, and the various esses of concrete were bound together by the insertion in them at irregular stone blocks which projected above each layer of te as laid. The upper 10 feet of this structure above the high-line is composed entirely of a filling of spoil from the founda-nd this is inclosed between the coursed facing.

same general mode of construction, a combination of concrete ibble, was used in the great diversion weir at Vir. The great am at Betwa is constructed of uncoursed rubble masonry coursed h faces; in addition to this the coping is of the best ashlar. ursed facing is laid with headers not less than 2 feet long and ers, two of which equal in height that of the headers. The al used in the rubblework is a kind of igneous granite, very nd excellent for the purpose. The ashlar work, however, con-f hard sandstone. In a few cases brick has been used for the uction of low weirs. A notable instance of this is the great ion weir at Narora, at the head of the Lower Ganges canal, which structed almost throughout of brick. This material has proved ly satisfactory, as the Narora weir is not very high and has to and but moderate pressures. The material used in the con-ion of the Tansa and Bhatgur reservoirs is a heavy trap or stone.

cement used almost universally in the construction of works in is of local manufacture, being made from dirty nodules of lime-which are found in the clay soil distributed very generally ghout the country. These limestone nodules are called kunkar, hen burned in a kiln produce an excellent hydraulic lime nearly ng the best cement in hydraulic properties and resistance to pres-Ordinarily these limestone nodules are comparatively small. est hydraulic cement made from these is that produced near Vir, head of the Nira canal. The nodules used for this are scarcely igger than a man's fist. In other places they are much larger, y in the Ganges Valley, where the material used in the construc-f the Lower Ganges head-works was found in lumps and blocks ing some hundred of pounds each. For the manufacture of ulic cement the limestone nodules are burned in a common kiln coke, charcoal, and cinders to hydraulic consistency. This ulic lime is then slaked and crushed, usually by means of the "us," big stone wheels drawn by oxen, though occasionally in

modern mortar mixers, and is then mixed with the proper prop of sand, either in the native mortar machine or more usually i an iron mortar mixer.

The stones used in the construction of uncoursed rubble ma are rarely larger than can be carried conveniently by two m almost all labor is manual, and rarely is carrying machinery The method of quarrying the stone and of transporting it by me tramways is similar to that employed in America and Europe. following are a few extracts from notes made by Mr. A. Hill, su tending engineer on the Bhatgur dam, on the masonry constr of that work:

In the facing the masonry is laid in courses, each of which does not e inches in depth, as large stones are too troublesome to handle. The sto wetted and the mortar and stones are well rammed. The stones for the are as large as can be conveniently handled by two men, while the smalle are broken up for metal to be used in making concrete. In uncoursed ru stones touch along their whole sides, not at points or edges merely, an chips are used to fill in spaces between the larger stones. All awkward pro are knocked off and the stones are well rammed into the bed of mortar i they are laid, and which must be at least 1 inch in thickness. The averag of these stones is perhaps 100 pounds.

The concrete is made of broken metal and river gravel, the former 3½-in the latter one-eighth to 3 inches; the proportions used are, metal, 16 part 16, mortar 12. The concrete is laid in two layers, each 4½ inches in t and rammed for twenty minutes and one hour, respectively, and is kept c wetted for at least two weeks, that it may set properly. The concrete both by hand and machine, the hand mixing being done on a floor w the machine mixing in iron barrels or mixers. The stone and gravel a before being mixed. Briquets of concrete used on this work, 15 by inches in dimensions, after six months' setting ruptured under a crushi of from 400 to 800 pounds per square inch.

In making mortar only sharp, clear, river sand is used. The lime, af burned to hydraulic consistency, is slaked for five hours, stirred and gr three hours more, and then clean wet sand is added in the proportion of stirred again for two more hours. For testing, this is made into 2-inch briquets, which are kept damp and are allowed to set for forty-eight ho which they are placed in water until tested.

The folowing are average tests of mortar made in this way a gur:

Average tests of mortar at Bhatgur.

Age 12 months, crushing weight per square inch	
Age 9 months, crushing weight per square inch	
Age 6 months, crushing weight per square inch	
Age 3 months, crushing weight per square inch	
Age 1 to 3 months, crushing weight per square inch	

Some briquettes stood as high a crushing weight as 1,100 per square inch when one year old. The hydraulic mortar use gives even better results. Several briquettes of mortar mad and mixed in proportion of 1 to 1 and from eight months to o

required a crushing weight of 1,500 pounds per square inch to ture them. Vir mortar mixed with 2 of sand to 1 of hydraulic breaks at 800 pounds pressure per square inch. The mortar used the construction of the Tansa dam showed an average crushing ngth of 800 pounds per square inch, though numerous specimens d a test of from 1,500 to 1,800 pounds per square inch.

t the head of the Ganges canal in the Northwest Provinces, the crete blocks used for groins in retaining works and for dams are peculiar composition, as hydraulic lime is scarce. They are com- d of 1 part quicklime to 3 parts of broken stone (about 1-inch e) and 2 parts of brick dust. These blocks are not very strong hydraulic. At this place the blocks which are used under the ter and subjected to the greatest pressure are composed of hydraulic e, 2 parts; sand, 1 part; broken stone, 3 parts. The Periyar dam, ich, as before stated, is constructed throughout of concrete, is igned to withstand a limit of pressure of 9 tons per square foot. e quantities of material have been estimated on the supposition at every cubic foot of concrete will require 60 cubic feet of solid one, plus 10 per cent for wastage, to 25 cubic feet of unslaked ydraulic lime.

DESIGN OF DAMS AND WEIRS.

As stated in speaking of reservoirs and storage works, the Indian ngineer designs the cross section of the dam on some theoretic pro- le which will be most stable and economical. All of these are sim- lar to the profile which has recently been discussed and described by Mr. Edward Wegmann in his treatise on the "Design and construction of masonry dams." Modified formulas, based on Rankine, Delocre, Krantz, or Bouvier, are generally used. Little value has been given to methods sometimes adopted of constructing the dam on a plan curved horizontally. None of the high dams seen in India were suffi- ciently short to have been curved in this manner. A formula for the design of cross sections which is generally employed by Indian engi- neers is that which was worked out by Mr. Guilford L. Molesworth in 1883, and is as follows:[a]

$$Y=\sqrt{\frac{.05\,x^3}{\lambda+(.03\,x)}}\,;\quad Z=\left(\frac{.09\,x}{\lambda}\right)^4$$

A vertical line being drawn from the top front edge of the dam to the base, Y is the width from this line to the rear face and Z the corresponding width from the line to the front face at any distance from the surface of the water or from the top of the dam. Y is further equal to $0.6x$ as a minimum; λ is the limit of pressure of the masonry in tons per square foot; H=top height of dam; a=Y at $\frac{H}{4}$ from the top; B=top width=$\frac{a}{2}$.

[a] Roorkee Professional Papers, Roorkee, India, 1883.

The accompanying diagram (fig. 56) shows how this formul applied. It is intended to secure the requisite stability at the f face when the reservoir is empty and at the rear face when it is This formula of Mr. Molesworth's, which has created considerabl cussion among Indian engineers, is considered an excellent empi formula for general use. Major Pennycuick, who designed the Pe

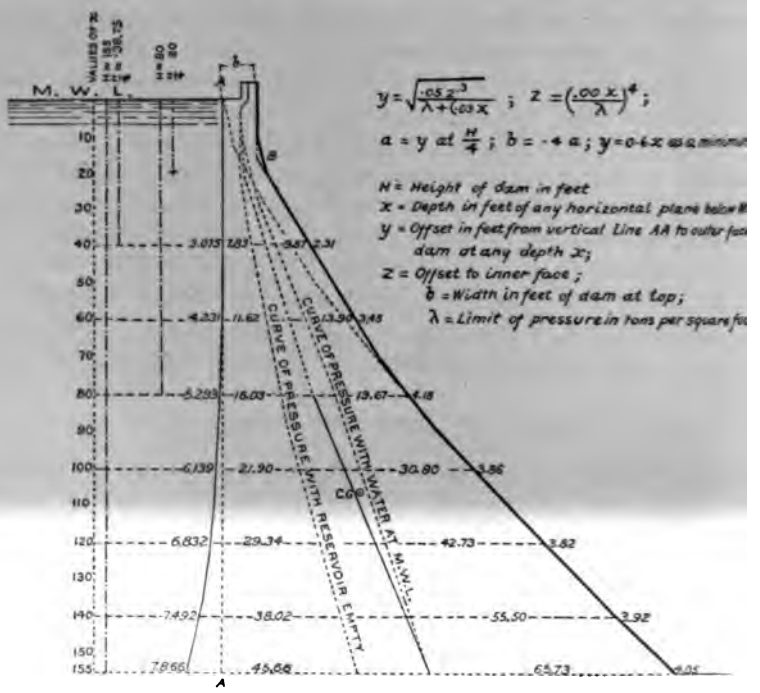


FIG. 56—Profile of masonry dam, Molesworth's formula.

dam, suggested a somewhat different formula,[a] and General Mu in his Manual,[b] proposes a modification of Molesworth's for which may be generally stated as follows:

$$y=b+\sqrt{\frac{.05\,(x-b)^3}{\lambda+.05\,(x-12)}}$$

with $b=12$, or for smaller top widths.

$$y=b+(12-b)+\sqrt{\frac{.05\,(x-12)^3}{\lambda+.05\,(x-12)}}$$

and adjusting the part above $x=12$ to the top width selected.

For weirs with water cushions the depth of the latter is som determined from the formula $D=c\sqrt{h^3}\sqrt{d}$ in which D represe depth of the cushion below the top of the retaining wall; c is a

[a] Periyar project. Records of the Government of India, No. CCXV, Calcutta, 1886.
[b] Mullins, Lieut. Gen. J., Irrigation Manual, E. & F. N. Spon, London and New York.

nt, the value of which is dependent upon the description of the aterial used for the floor of the cushion, and varies between 0.75 for mpact stone and 1.25 for moderately hard brick; h is the height of e fall, and d is the maximum depth of the water to pass over the ir crest. The width of the floor of the cushion will depend somenat on the section of the weir, which need not exceed $8\sqrt{d}$, and ould not be less than $6\sqrt{d}$. For works with a vertical drop and a rizontal apron on the same level as the retaining wall, this masonry ron should be formed of fairly regular blocks of stone or of Portnd cement concrete, the width varying as just given, and the ickness or depth of stone from one-fifth to one-fourth of $h+d$.

It is difficult to find any set rule for determining the depth of the ater cushion by the height of the fall and the volume of water. At e Gairsoppa Falls, in the Western Ghauts, the Rajah Fall has a ear drop of 825 feet in height, and the pool into which it falls is 138 et deep at low-water stage. The greatest depth of the hole formed y the waterfall in the new outlet of the Mudduk Masur tank is 24 et. In ordinary states of the river the general depth of the water ushion is to the height of the fall as to 3 to 4 where the greatest tion takes place and 1 to 2 in other places. An experimental fall n the Bari Doab canal had a height of 6.9 feet and depth of well of feet, and 3.6 feet on crest, which gives the depth of the well to the eight of the fall as 3 to 4. The water had no injurious effect on the ottom of the well. The subject of water cushions is one which is ot very well understood, though these are very extensively used in ndia. They appear to be a most effective and interesting addition nearly every weir where they are placed, greatly increasing its tability and firmness.

COST OF LABOR AND MATERIAL.

It has generally been held that owing to the great relative cheapess of labor in India, compared with that employed in the United tates, few lessons, especially of a financial character, could be drawn om a consideration of the results of Indian irrigation works. The ports on the returns derived from Indian works, the percentage of rofit gained or loss incurred, are not of the most encouraging charter. A thorough examination of this matter, both in the field and the reports, has, however, allayed any doubts which I had on this ubject, and leads me to believe that yet better results may be btained in the United States, even in comparatively uninhabited gions.

As was shown in the earlier part of this report, the returns derived India from works constructed with borrowed capital on such works the perennial canals of the Northwest Provinces show profits arying from 4 to 20 per cent per annum. It was also shown, howver, and this is the least promising phase of the investigation, that

in scarcely any case had storage works been profitable. The la
most cases on this class of works has been trifling, while in se
cases a profit has been gained. Moreover, the older works of this
are rapidly becoming more popular. The value of irrigation is be
ing better appreciated, even where a constant rainfall occurs, and
works are annually increasing in value.

It was soon seen that any attempt to ascertain the relative
both cost and return, of works constructed in India by compari
the rates of labor paid in that country and in America, was alto
futile. Notwithstanding the remarkable cheapness of all clas
native labor, the relations of the laborer to the government, the
acter of the laborer, and the exhausting heat of the climate, al
to make his day of labor a relatively short one, both in time a
work done. Few or no mechanical appliances are yet used in th
struction of Indian works. It is claimed by some that the se
cheapness of the labor seduces the engineer. This in most c
not true. The average engineer appreciates the value of labor-
machines, but has contended so long with the carelessness of the
laborer and his lack of interest in learning new ways that he has
given up the struggle of trying to teach him to use modern
ances, feeling convinced that the native cooly achieves as good
in his own way as he could with better apparatus which he wou
use or fail entirely to avail himself of.

The long time required in the excavation of works, in filling
ing, and emptying a little basket which holds perhaps a shov
dirt, tends decidedly to make the native labor expensive. T
mode employed of carrying comparatively small stones for
struction of great dams, consisting of tying ropes around the
attaching them to poles, having them lifted onto men's should
the aid of assistants, then making a slow, plodding journey f
stone pile to the top of the dam, all tend to increase the expen
labor employed (see Pl. XXIV, *B*). In the construction of su
in the United States, machinery would dig the canals in gr
and a vigorous, skilled workman, using with intelligence labo
appliances, would in a day accomplish many times the amount
that is done by the Indian cooly. In every individual ope
seen the slowness of native methods. If it be grinding mort
walk in a circle drawing a large stone wheel attached to a
beam, which laboriously and slowly grinds the mortar as the o
can arrastre grinds the quartz. Occasionally a modern mort
seen operating beside the native churus and doing in a few
the work which the latter take hours to accomplish. In the bla
shop half a dozen men are needed to perform the work of on
forge is blown by a boy, who pumps air through a couple of
bags beneath his arms, taking much more time to create t
degree of heat than a modern blacksmith's bellows would req

The works constructed in India are invariably of the most substantial masonry and will last for centuries. Along the roads and railways the smallest bridges and culverts are constructed of stone and brick. On the canals the least important regulator, aqueduct, or bridge is likewise constructed of the best masonry for all time. In the construction of such works, iron and timber would be extensively used for bridges and aqueducts, or, as we call them, flumes, and for many parts of the head-works and works along the canal lines, thus greatly reducing the cost.

Another great expense incurred on Indian works has been the effort to combine navigation with irrigation. This effort has been comparatively unsuccessful if viewed from the light of the modern requirements of a country possessing good railways and wagon roads. As before stated, in order to make the canals navigable their expense is greatly increased by the construction of locks throughout the whole length and of parallel canal channels; of bridges of greater headway, in order to admit boats to pass under them; and of expensive aqueducts or similar works, instead of the cheaper contrivances which might be used if navigation were not practiced. Above all, navigation entails great loss of water.

In the neighborhood of Poona labor is perhaps as cheap as anywhere in India. It is performed by all classes, ages, and sexes, the more skilled laborers, as masons, carpenters, and blacksmiths, usually being Brown men. Most of the burdens, as gravel, sand, mortar, and materials which have been excavated, are carried away on the heads of women and children. Common labor is paid about 8 cents per day. Masons and carpenters get from 16 to 20 cents a day, while a laborer with a team of bullocks gets 25 cents a day. On the Bhatgur dam donkeys and bullocks were frequently used as pack animals for carrying stones and earth. A donkey will carry a cubic foot of stone per trip and earns 6 cents a day. Common laborers were paid 8 cents, women and children 4 cents, and skilled laborers 20 cents per day. It was estimated that 8 skilled masons could lay and dress 3 cubic yards of masonry per day on this work. Owing to the slow mode in which the work was conducted it was necessary to employ a great number of laborers at one time, so many in fact, that a large portion of them were frequently idle through interference with one another. About 2,000 men, women, and children were engaged on small portions of the dam at once and the daily rate of progress was about 5,000 cubic feet of rubble and concrete work and 1,000 cubic feet of course masonry facing.

At Tansa the work was done by contract, and the prices paid were a little higher than elsewhere. Rubble masonry cost $3 per cubic yard. On Lake Fife and Bhatgur the same class of good uncoursed rubble masonry cost but $2 per cubic yard. On the Tansa dam over 5,000 people were at work at one time. On the Betwa canal earth

excavation in deep cuts, not exceeding 40 feet in depth, cost but 6 cents per cubic yard; surface excavation in earth with short haul cost 3 cents per cubic yard; uncoursed rubble masonry cost $2.30 per cubic yard; coursed rubble masonry, $6.25 per cubic yard, and dressed ashlar work $22.50 per cubic yard. On the Periyar works the ordinary price of unskilled labor was 12 cents per day; for special work, such as feeding machinery, etc., the coolies were paid 20 cents per day; while head coolies, artisans, etc., were paid from 30 to 60 cents per day.

All kinds of material other than those found in the country itself are most expensive in India. Coal is usually brought from England at a cost never below $20 per ton. Iron, steel, and machinery are relatively very expensive, as is Portland cement and wood of every kind. In fact, masonry work is generally cheaper than wood, and iron is always dearer than masonry. The great cheapness of masonry is owing to two causes—cheapness of labor, and cheapness of the hydraulic lime which is manufactured in the country almost invariably near the site of the work which is being constructed. On the Periyar work drilling cost $10 per hundred running feet of drill hole, and the labor of quarrying, including plant, boring, dynamite, and all other expenses, amounted to about 85 cents per cubic yard, or as much as it would in the Western States of America. On the same work in tunneling, the heading cost $6.50 per cubic yard, and for enlarging the tunnel $2.60 per cubic yard was paid; lime cost $1.30 per cubic yard, sand 40 cents per cubic yard, and concrete cost $1.70 per cubic yard laid in place. Of minor items, the removal of earth or cutting cost 6½ cents per cubic yard, steel 15 cents per pound, and wrought iron 8 cents per pound. On the Sidhnai Canal, in the Punjab, concrete cost $1.80 per cubic yard, rubble masonry $2.16 per cubic yard, and brick 95 cents per hundred laid in lime mortar. Earth excavation cost 4½ cents per cubic yard, and the best hydraulic lime cost $2.50 per cubic yard to manufacture.

TANKS.

Tanks were constructed in great numbers by the natives of India many centuries ago, and in some places, notably in central and southern India, in the Deccan, Madras, and Mysore, there are immense numbers of them. These old tanks were usually rude in construction, little care having been taken to economize in labor, and as a consequence the dams constructed were usually made much heavier in cross section than was necessary. In recent years the British engineers have constructed several very large tanks, though many of the higher dams have masonry cores. The conditions controlling the location of a tank are similar to those before described for reservoirs. The water supply must be adequate to fill the tank, the location must be such that a suitable dam can be constructed at a reasonable cost, and an ample wasteway must be provided. In the location of the

wasteway for a tank, even more care must be exercised than is necessary for a reservoir; for if the water be permitted to rise too high on the dam—or much worse, if it is allowed to discharge over it—it will speedily cause its destruction if it is built of earth.

It is desirable always to allow waste water to flow off by a side channel, which may be closed by a low rock or crib-work weir, or may consist only of an open rock cut. By such means there is no danger to the dam of having the shock of water falling over it. It may, however, be necessary to have a masonry wasteway constructed in the dam itself, but this is not advisable and is generally avoided. Such wasteway is usually made by constructing a portion of the dam of masonry, the top of which is a few feet lower than the rest of the dam. When the catchment of the tank is small it is possible to provide for wasting flood waters through an outlet or discharge channel in the dam itself. Such a discharge sluice is necessary in order to draw off the water for irrigation, and must be of sufficient capacity to empty the tank in the shortest irrigating season. The level of the sill of this outlet sluice is generally that of the bed of the tank, but there are occasionally constructed one or more higher outlets to irrigate lands which lie above that level. These sluices are expensive works, and require a well-constructed masonry or iron conduit to be carried through the dam, emptying into the canal at one end and receiving its water supply at the other end through a well or water tower from which its admission can be controlled. It is usual to make the outlet tunnel of good masonry, and it must not be smaller than 4½ feet high by 2 feet wide, in order to permit a man to go through it to examine, clean, or repair it, if required.

One cause of the frequent breaching of Indian tanks is that great numbers are often constructed in one valley, the bed of one beginning where the cultivation of that of the next above it ends, so that the breaching of one often results in the destruction of a succession of those below it. Regarding the depth of tanks, if they be shallow a great loss of the stored water is sustained through evaporation. Shallow tanks are never intended to hold more than water enough for one crop. In India aquatic plants which grow from the bottom in shallow tanks are injurious, while those which spread on the surface, like the lotus, diminish the loss by evaporation. When water is not deeper than 7 or 8 feet the rays of the sun can penetrate to the soil, and growth of aquatic plants is the consequence. In the smaller tanks, intended to cultivate limited areas of land immediately below them, the most economical height for the dam on gently undulating ground where there is a natural and long slope to the rear has been found to be from 10 to 25 feet.

In the construction of modern tanks the same precautions are usually taken and the same detailed investigations made as for a reservoir project. The catchment basin, the discharge of the streams, the rain-

n accident is obtained by raising a low masonry parapet on er edge of the slope, paving the top, and giving it a slight dip to prevent the settlement of water.

number of disused tanks is remarkable. Many are not ed, but the discharge sluice is left open so that no water is ed. In many cases this is probably owing to the bed of the aving been gradually raised by silting and thus converted into luctive a soil that it yields as much as or more than could be ed by means of a diminished quantity of water applied to the atively barren soil below. An example of one of these old thus abandoned, but capable of restoration, is the Madag tank, believed to have been constructed about four centuries It was formed by an embankment rising from the sides of a gorge through which the Choardy River passed, and was nented by two dams in saddles on a range of hills, that on the nk 1,350 yards and that on the west 760 yards from the main ne length of the latter being 1,650 feet. The inside slope of 1 in some parts 1 on 3, was revetted with large stones up to a yard in bulk. This dam is from 945 to 1,100 feet wide at the id is now from 91 to 108 feet high. There was a sluice under n at the east end above the level of the ground. The material ch the dam is constructed is a strong red earth with a con- ole mixture of gravel, and was taken from the sides of a hill in ighborhood. The east supplemental dam has its base 74 feet the sluice in the main dam, and had also a sluice under it at ound level. The west supplemental dam, the breaching of destroyed the tank, was of similar construction to the others, base was 60 to 70 feet above the bed of the tank. There was e of any wasteweir, and it is probable that the want of this e cause of the ruin of the tank. From the heights of the nd the levels of the sluices it is probable that the depth of the as 90 to 95 feet, and at that level its area would have been 40 miles and its contents about 870,000 acre-feet of water.

her variety of tanks, constructed not on main drainage lines or s but in depressions in a flat country, are usually closed by a it form of dam. There were many of these, and large numbers eached or abandoned and their beds now cultivated. The kments of these flat-country tanks are often of great length, usually 1 or 2 miles; that of the Veeranum tank is 12 miles nd the ruined bank of the Puniary tank in the Trichniopoly is said to be 30 miles long. The height of these is generally derable, being in many hundreds of cases only sufficient to hold to 10 feet of water. A few of these works, however, are 20 or ven 50 feet in depth. The inner slope is generally revetted with nd has an inclination sometimes of 1 on 1, oftener of 1 on 2 or The height of the bank above the water level varies. For

instance, the Nundyal tank has a dam at one place 18 feet high, 2 feet above the water level, 16 feet wide on top, with an inside slope of 1 on 1 and an outside slope of 1 on 2. The Kolevoy tank, in the Nellore district, has a bank 36 feet high, extending 9 feet above the water level, a top width of 12 feet, and equal slopes inside and outside of 1 on 1½.

As the accumulating alluvial deposit made year after year gradually raises the beds of tanks, these would become filled up were not some expedient adopted from time to time, such as adding to the height of the dam. This, however, generally involves an enlargement of the cross section as well as the raising of the wasteweirs and the construction of new sluices at higher levels than the one occupied. One expedient frequently resorted to successfully is to have the mud stirred up by hand at the beginning of the rainy season when the flood waters are permitted to carry it off through the discharge sluices. This, however, is only partially effective, like the scouring of the understuices in a reservoir.

In central India there are many tanks; their history is rather modern and is very interesting. In 1820 the Mairs, a tribe occupying Marwar, Meywar, and Ajmere, were banditti living in the hills, constantly fighting and making raids on the Rajputs and other neighboring tribes. The Mairs lived chiefly by levying blackmail on isolated hamlets and on travelers. Col. H. Hill subjugated them, and by the establishment of a government, police, etc., caused them to live more peaceably and to commence the pursuit of agriculture. In 1835 Colonel Dixon succeeded to the charge of the Mairs and arrived at the conclusion that the lack of water, rendering agriculture impossible in a country whose rainfall was below 20 inches, was the cause of their predatory life. Their history from this time was similar to that of the nomad and bandit tribes which occupied the country now irrigated by the Sirhind Canal in the Punjab. Colonel Dixon commenced by causing the construction of terraced irrigation lands by means of retaining dikes, and of tanks by means of earth or masonry dams.

Having been furnished with an abundant water supply for fertilizing the crops, the Mairs have, owing to this enlightened policy of Colonel Dixon, now become peaceful and industrious cultivators. The small tanks furnish water for irrigation below them and water for wells near them, and when the water is drawn off their beds are cultivated, and, being very fertile and moist from the deposition of sediment, produce excellent crops. These tanks now support a large population and produce considerable revenues.

The following table exhibits the principal dimensions of some of the Mairwara tank embankments and weirs:[a]

[a] Smith, R. Baird, Italian Irrigation, William Blackwood & Sons, London, 1855, vol. 1, p. 420.

Dimensions of some of the Mairwara embankments and weirs.

Name.	Length of embankment wall or weir.	Breadth— In foundation.	Breadth— At upper surface.	Depth of foundation.	Height above foundation.	Spread of water.	Area irrigated, including cultivation in bed.	Cost.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Acres.*	*Acres.*	
a	620	27	10	9	24	182	204	$3,125
ja (escape weir added to ient embankment)	251½	28	.....	6	16	218	364	1,890
ana weir	522	10½	3½	0	18	25	36	1,100
Kuncur	3,369	42	6	0 to 10	28	182	437	8,275
na	460	25	4½	10	28	94	250	2,135
weir, upper	240	30	7	8	36	72	100	2,000
ower	343	12½	6½	10	20	72	29	1,280
nee	575	29	.....	20	24	218	273	810
a Bura	954	5	3½	6	14	36	83	.....
tan	1,333	21	.....	19	16	145	328	.....

ıe following table exhibits the results of some of the works detailed 'e, showing the increase in number of families, of wells, and of ge tanks, etc., during eleven years preceding the preparation of nel Dixon's report, 1835 to 1846:

Results of Mairwara embankments.

Name of village.	Increase in number of— Families.	Wells.	Village tanks.	Increase in revenue.
.....	38 to 133	3 to 46	0 to 31	$235 to $1,030
a	25 to 122	8 to 28	0 to 15	125 to 895
Kunkar	0 to 118	0 to 25	0 to 14	0 to 545
.....	70 to 440	131 to 301	.....	1,925 to 4,425

, following table shows the whole number of tank embankments ·ucted in Mairwara up to the date of the report:

Tank embankments in Mairwara.

Districts.	Number of embankments and weirs.	Spread of water in bed.	Area irrigated, including cultivation in bed.
		Acres.	*Acres.*
Mairwara	158	6,323	10,557
Mairwara	120	3,077	3,960
Mairwara	12	275	309
al	290	9,675	14,826

From the above it will be seen that between the years 18
the increase in the number of wells was from 2,530 to 6,15
The increase in the number of tanks was from nothing to
estimated population increased 60,000 (from 40,000 to 100,00
revenue increased from $48,000 to $105,000, or $57,000. The
sums expended under the sanction of the government in all
during the same period of years was $125,000, while the
increase in land revenue for the same period amounted to $

Lieutenant Home, in 1868,* reported on six principal tank
water the average capacity of which ranged from 920 to 2,40
The total outlay on these to the end of the year 1863 was $40,
net income to the end of the same year was $2,000, or a net
ing between 1 and 12 per cent. The results of Lieutenan
inspections showed that not only have Colonel Dixon's w
mously benefited the country, but they have returned the g
130 per cent on the expenditure incurred. The whole of the
especially mentioned paid nearly 10 per cent on the capital

In Mysore in southern India there are 37,000 tanks, of
Robert Temple says:

Wherever there is a depression in the land an embankment with
and a sluice is thrown across it. The water is held up above it, and be
acres are sown with rice and sugar cane, and irrigated by means of
few yards lower down the depression comes another, and so on, incre
as they go on until a series of tanks may consist of more than one hund
nected together, the overflow from the wasteweir of each being the c
of the one below it and the stream that issues from the wasteweir of
one being a river in magnitude. The tanks at the top of the series are
and those at the bottom are often good-sized lakes, and the area irrigat
is frequently very large.

In Madras Presidency, including Mysore, there are said to
71,000 tanks. All of the smaller tanks are repaired either b
lages or by the landowner. The smaller tanks are used d
rainy season chiefly in order to keep up a constant supply of
the fields during the intermission of the rainfalls. The lar
contain water supply sufficient often for one year and some
several years. In Mysore, early in 1896, Major Sankey† repo
the percentage of the whole area of Mysore under the tank sy
39.7, while the total area of the state is 27,300 square miles.
under exceptional circumstances, none of the drainage of 6
of this area or 16,300 square miles is allowed to escape.
should, with proper attention, be allowed to escape, were all
works in their normal condition. To such an extent has the
of storage been followed that it would now require some ing
discover a site within this great area suitable for a new tank.
Major Sankey said that "one-third of the tanks then existing i

* Home, Lieut. F. R. E., Tank irrigation in Ajmeer and Mairwara. Roorkee
Papers, No. 29, Roorkee, India.
† Sankey, Maj. R. H., R. E., Irrigation in Mysore. Roorkee Professional Papers on
C. Roorkee, India.

were large irrigating reservoirs." He found about one tank to the square mile and one village to the same area; the average quantity of cultivation was about 10 acres to a tank. In this area there are some great tanks, such as the Mudduck and Nuggar tanks mentioned elsewhere.

The ordinary Mysore tank is, however, a much smaller description of work, usually closed by a low and long dam; an average one being about 12 feet broad at top, 60 feet wide at bottom, and 18 feet high. In this description of tank the sluice is usually a large, substantial, and not infrequently expensive work. It consists of a square brick or stone cistern, 2 yards each way and 1 yard high, to keep off the sand at the entrance of the sluice, with one or more valves or plug holes in a stone at the bottom, from 6 inches to a foot in diameter each. The valve is attached to a long pole which is held in an upright position by 2 or 4 vertical stone pillars, to which horizontal projections are attached, one at top and another midway down, through a hole in the center of which the valve rod works. The pressure of the water upon the top of the valve keeps it sufficiently tight when lowered into the valve hole to prevent the escape of water. At the rear of the dam another cistern of about the same dimensions, and usually of brick in mortar, is built, three sides of which are furnished with square openings and shutters to permit the water being turned off. The two cisterns are connected by a tunnel, the length of which depends upon the cross section of the dam through which it is laid.

Most tanks receive their supply from the high ground in the neighborhood; but there are exceptions to this, as numerous tanks are partly supplied by channels, either from water courses or canals, which wind around remote hills and catch the rain flowing down their sides and convey it to the tanks. A single tank may possess several feeders of this kind. Many old tanks which had failed during the early native government have been restored by the British engineers; others which were decayed have been repaired, and a few which were tolerable have been put in perfect order. None of these irrigation works have deteriorated since the British took possession, and their condition on the whole has been greatly improved. Judging from various reports the works are probably now in a more effective condition than at any other time of which we have a record, and the increase in efficiency has apparently kept pace with the increased liberality in the expenditure, taking no account of the great rise in labor rates of late years.

In the Madras Presidency mainly, exclusive of Mysore, there were reported in 1882 to be 53,000 tanks, having about 30,000 miles of embankments and 300,000 separate masonry works, weirs, escapes, etc., yielding a revenue of $7,500,000 per annum, and having invested in them a capital of $75,000,000. In 1882 the area irrigated for first or wet-weather crop amounted to 2,525,790 acres, and the area of autumn crop irrigated in the same year by tanks amounted to 675,400 acres. Some of these Madras tanks are, as before stated, of immense

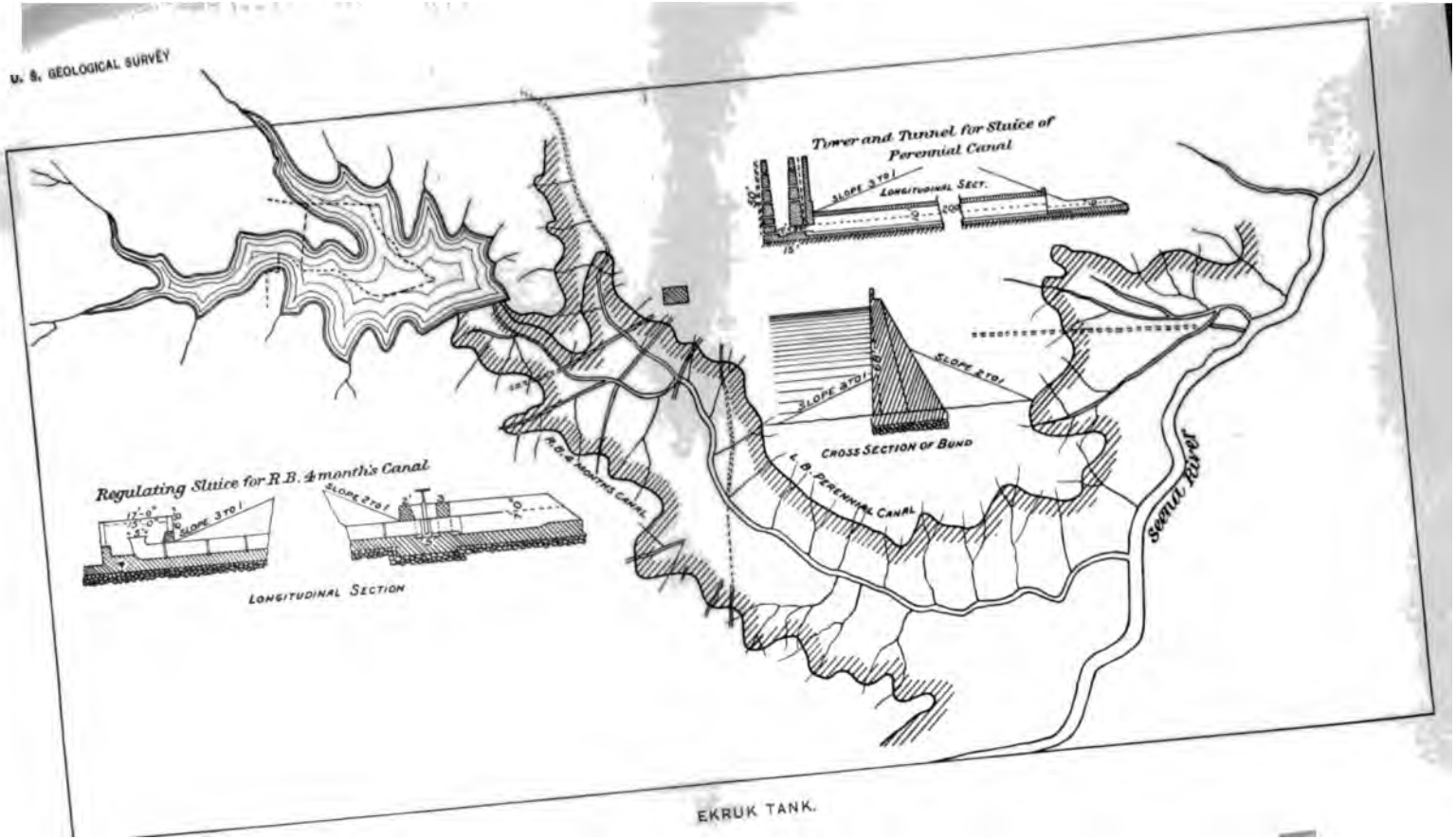
The Viraiyum tank, which is a very ancient work, has an ar
square miles and an embankment 12 miles long. It is still
operation and returns an annual revenue of $57,000. The Ch
lankam tank in Chingleput is so large that it resembles a great
lake. Its embankment is more than 3 miles long, and its wa
have a total length of 676 feet of escape. Its gross capacity
acre-feet, its surface area is 8.95 square miles, or 5,730 acre
irrigates of wet-weather crop 12,700 acres, and of autumn cr
acres. The dam which closes this reservoir ranges from 9 t
in thickness at the top, and from 16 to 28 feet in height, and
structed of earth. It supplies irrigation to the fields by mea
separate sluiceways. In 1882 the capital invested in this w
reached $312,000, and the revenue for that year amounted to

Some of the most interesting tanks to be found in India,
they are the most modern, are several of the great tanks reco
structed in the Bombay Presidency, which are more truly r
than tanks, as the latter term fails to convey a proper idea
magnitude and importance. Of these, the more important ar
esting now in operation are the Ekruk tank near Sholapur,
Ashti tank, also in the Sholapur district, and constructed on t
River.

The following table gives some of the more important data co
with these tanks, and is derived from the Bombay revenue re
1900–1901:

Tanks in Bombay Presidency.

	Ekruk.	Ashti.
Area of catchment ..... square miles..	159	92
Average annual rainfall ..... inches..	30.7	26.7
Available contents ..... acre-feet..	76,130	32,660
Surface area ..... acres..	4,551	2,380
Area commanded ..... do....	17,152	17,882
Area irrigated ..... do....	16,941	11,780
Main canal ..... miles..	48	27
Distributaries ..... do....	.....	2
Height of dam ..... feet..	76	57.7
Total cost ..... dollars..	953,000	278,000
Area irrigated:		
Autumn ..... acres..	1,620	989
Summer ..... do....	1,355	1,440
Total ..... do....	2,975	2,420
Percentage double cropped	1.2	6.3
Discharge utilized ..... second-feet..	33.3	9.2
Area of autumn crop irrigated per second-foot of discharge utilized ..... acres..	40.8	155.8


Tower and Tunnel for Sluice of Perennial Canal
SLOPE 3 TO 1
LONGITUDINAL SECT.
SLOPE 3 TO 1
SLOPE 2 TO 1
CROSS SECTION OF BUND
L. B. PERENNIAL CANAL
R. B. 4 MONTHS CANAL
Regulating Sluice for R. B. 4 month's Canal
SLOPE 3 TO 1
SLOPE 2 TO 1
LONGITUDINAL SECTION
Seena River

EKRUK TANK.

EKRUK TANK.

The catchment area of the Ekruk tank is 159 square miles, on which the annual rainfall averages 24.7 inches and the run-off 41,400 acre-feet, or 4.87 inches per square mile. The rainfall on the irrigable lands served by this tank averages 22.8 inches per annum, the duty of the water supplied during the four months' autumn crop was 76 acres per second-foot, and the water rate charged on the land served during the year 1888 was 86 cents per acre irrigated or $73 per second-foot of discharge at the canal head. The crops raised in 1888 were distributed about as follows:

Crops raised on land irrigated from Ekruk tank.

Crop.	Acres.	Value.
Wheat	337	$3,100
Sugar	260	17,300
Millet	344	2,307
Beans	537	2,700
Total, including all others	2,976	38,000

This work was undertaken by the Indian government and is situated 5 miles northeast of the town of Sholapur. The scheme, drawn up in 1863 and sanctioned in 1866, comprises a tank formed by an earthen dam and supplying three canals for irrigation. It receives its water supply from the River Adhila, a tributary of the Lina, the fall of which is 7 feet per mile, and its greatest flood discharge is 37,000 second-feet. The dam which forms the tank has a total length of 7,200 feet, including 2,730 feet of masonry, of which 1,400 feet is at the northern end and 1,330 feet at the southern end. The maximum height of the earthwork above the bed of the Adhila River is 72 feet, or 7 feet above the highest flood line. The height of the masonry portion is 3 feet above the highest flood, exclusive of 3 feet of parapet above that. When full the maximum depth of the tank is 60 feet, and its contents 41,700 acre-feet of water, the surface area of which is 6½ square miles. The wasteway is at the northern end of the dam, and consists of a channel 250 feet wide carried through a spur and discharging into a side drainage course. The calculated maximum velocity over the wasteway is 10 feet per second, and its capacity of discharge is 250 by 5 by 10 = 12,500 second-feet. The depth of evaporation during eight months is 7 feet, and the loss amounts to 17,250 acre-feet.

This tank has three discharge canals. The accompanying Pl. XXVI gives some details of this work. The lowest or perennial canal is 28 miles long, and its sill is 20 feet above the level of the bottom of the tank. Its discharge amounts to 44 second-feet and it cov-

gable area of 25 square miles. The next canal above this is intended to provide a four months' supply of water; it is 18 miles long, discharges 42 second-feet, and covers an irrigable area of 21 square miles of land. The highest canal is also calculated for a four months' supply, and is 4 miles long and discharges 21 second-feet of water. The discharge of one of these four-months' canals is compensated for by the supply of rain received during the rainy season. The lower perennial canal is taken from the left bank, the second canal from the right bank, and the higher canal from the left bank. The discharge sluice at the head of the perennial canal consists of a masonry tunnel through the canal bank, with a substantial masonry inlet tower on the water side. The diameter of the tunnel through the dam is 12 feet, and its total length is 200 feet. The discharge sluices for the four-months' canals consist of an iron pipe 145 feet in length and 5 feet in diameter through the dam, which is closed at the lower side by means of a valve worked by hand gear from above.

According to the revenue report for 1900–1901, the total outlay on the Ekruk tank to the end of that year amounted to $953,000, the total receipts from irrigation during the year were $3,040, and the gross receipts from all sources amounted to $8,030; the total working expenses amouted to $2,660, showing a net revenue of $5,370, equivalent to 1.2 per cent on the capital outlay. As originally designed, this work was estimated to yield a net revenue of 9 per cent on the capital expended. Its failure to do this is largely due to the small demand for the water, owing to the natural rainfall on the district served being ordinarily sufficient to raise crops without irrigation.

ASHTI TANK.

The catchment area of this tank is 92 square miles, and the rainfall over this area averages 24.1 inches per annum; the run-off amounts to 8,000 acre-feet per annum, or 1.62 inches per square mile. The rainfall on the irrigable lands served by the tank averages 19.8 inches per annum. The project comprises a tank on the Ashti River, formed by an earthen dam 12,709 feet long and 58 feet in maximum height, having a total storage capacity of 34,500 acre-feet of water. There are two discharge canals, one on each side of the Ashti River, which extend to its junction with the Bhima River and command 25,270 acres of irrigable land.

This work is situated in the Sholapur district, about 16 miles southwest of the town of Madha. The project was originally prepared by Capt. C. B. Penny, R. E., in 1869. In 1876, when the great famine was imminent and the prosecution of relief works was urgently called for, this was one of the first works undertaken for that purpose. The project (fig. 58) was then thoroughly revised and complete plans and estimates prepared by Mr. Charles T. Burke[a] under the orders of Col.

[a] Burke, Charles T., The Ashti tank: Proceedings of the Institution of Civil Engineers, vol. 76, *part 2, 1883*, London.

[illegible] J. Merriman, R. E., chief engineer. The available capacity of the [illegible]nk is 32,660 acre-feet, and to furnish this quantity a run-off of 6.3 [illegible]ches per annum would be required from the catchment basin. The [illegible]n-off during an average season is but 6 inches, or 4.87 per cent of [illegible] available capacity of the tank. The features of the ground, how[illegible]er, do not admit of the capacity of the tank being reduced, as the [illegible]vel of full supply was regulated by the only saddle available for the [illegible]asteway. Had that been lowered the quantity of rock excavation [illegible]ecessary would have cost more than the earthwork required to raise [illegible]e dam, besides which there is manifestly an advantage in making [illegible]e reservoir of large capacity if it can be done without increased [illegible]pense.

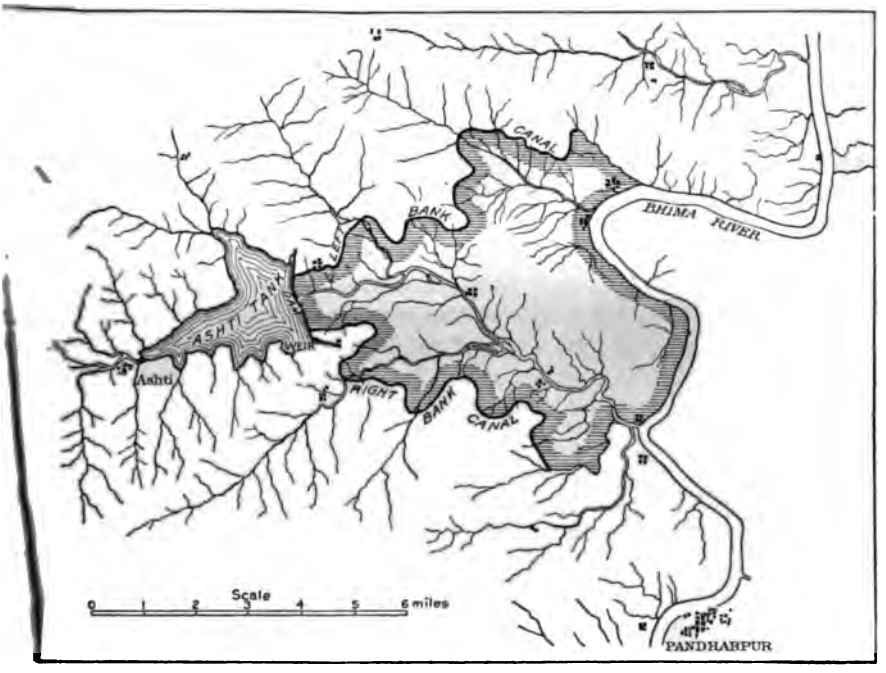
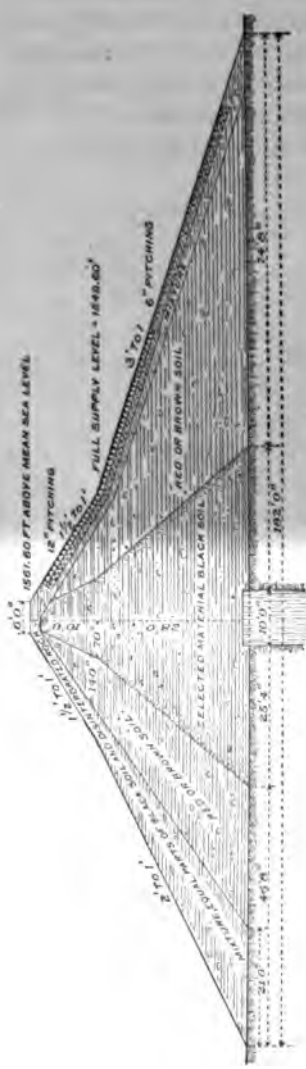


FIG. 58.—The Ashti tank and canals.

The loss by evaporation, absorption, etc., was estimated at 4 feet in depth on half the area at full-supply level. From actual experiment after the completion of the work it was found that the loss from evaporation in 1880 during the six winter months of dry weather was 3.8 feet; deducting this quantity the net supply of water available for irrigation is 25,300 acre-feet.

The total length of the dam is 12,709 feet. Its top breadth is 6 feet, its breadth at full-supply level is 42 feet; the side slopes above this point are 1 on 1½ below it, the inner slope is 1 on 3, and the outer slope 1 on 2. Previous to its construction the site of the dam throughout was cleared of vegetable and loose material, and the sand and silt were removed from the entire area forming the site of the dam in the

river bed. Thus the dam throughout rested upon a sound an foundation. There is no puddle wall, but a puddle trench, the of which rises 1 foot above the ground surface, extends throu the whole length of the dam, and is 10 feet in width, and ha excavated down to a compact impervious bed. Its compositi parts sand and 3 parts of blac The central third of the dam i up of selected material of blac extending, as shown in the accom ing illustration (fig. 59), in a tria section, from the dam crest, whe 6 feet wide, to the base, where i feet wide. Outside of this are t angular sections composed of the soil of the country, and this is outside with from 1 to 15 feet of of sand and black soil, while a puddle on the inner slope is pav 6 inches of large stone pitchin able it to resist wave action. the river bed a trench 5 feet i was excavated along the entir of the dam down to the rock tending 100 feet into the bank river. On each side this was fil concrete and was connected puddle trench. The puddle tr curved around the concrete continued across the river at a of 20 feet from the concrete wa upstream side.



caused the removal of a large quantity of sand from the site at a small expenditure. A low dam of dry rubble work was then constructed across the river about 100 feet above the site to prevent it from again being silted up, and during the dry season the work was carried up in the ordinary manner.

The pitching given to the inner slope of the dam was calculated as follows:

The thickness of the pitching depends upon the greatest height of the waves to which the dam is exposed, and the maximum height of the waves depends upon the "fetch" or distance from the shore where their formation commences and was determined by Stevenson's formula

$$x=1.5\sqrt{F}+(2.5-\sqrt[4]{F})$$

where x = the height of wave in feet, F = the fetch in nautical miles. Again, Rankin states that where an embankment of loose stone is exposed to the action of waves it must be faced with blocks set by hand, the least dimension of any block in the facing being not less than two-thirds of the greatest way height. From these two considerations the thickness of the pitching was deduced.

The cross section of the Ashti dam is considered to be amply strong in every way, yet Mr. Burke deems it well to consider whether in works of such magnitude the adoption of a more liberal cross section would not be advisable. He says that the Ekruk tank dam has a top breadth unnecessarily great and not uniform, as it is diminished in proportion to the height. This does not improve the appearance of the dam, is unnecessary under any circumstances, and involves an increased outlay. The top breadth of the Ashti dam is too narrow, for, although sufficient in strength, Mr. Burke considers it objectionable for various reasons. A dam of this kind would warrant, if but for appearance alone, as well as for the convenience afforded by a roadway, a small outlay to increase its top breadth sufficiently. In preparing the plans of the Pangoan tank which was subsequently designed by Mr. Burke, the top breadth was increased to 8 feet, and even this appears insufficient for a dam 77 feet in height. Mr. Burke recommends the following as a minimum top width for works of this nature in India: For earthen dams 50 feet in height and over, top breadth to be 10 feet; under 50 feet in height, 8 feet. In the course of time settling may occur in dams constructed wholly of earth, rendering repairs and renewals necessary. In the first ten years after the completion of the Ekruk dam, 2½ feet in depth of new material was added to its top, and this could not have been properly rolled solid if the roadway had not been sufficiently wide for compression by a heavy roller.

The change of inclination from 1 on 2 to 1 on 1½ of the outer slope of the Ashti dam is undesirable. As regards the inner slope, the incli-

nation of 1 on 3 up to the level of the estimated maximu appears to be good. This should then change in tanks to 1 the top of the dam. It is a matter for consideration whether th part should not be 1 on 1, rather than 1 on 1½. It would prob an advantage, Mr. Burke thinks, that waves should be reflecte than broken on the slope, and on the authority of Mr. Scott R appears that a slope of 1 on 1 will reflect waves, while on flatte they are broken. The cross section recommended by Mr. B general adoption in India is as follows: The height of the da the full-supply level, or the crest of the weir, is $h=d+x+c$; i d = the depth of water in the tank above the weir-crest level maximum flood is flowing over the weir; x = the height of th pitching above the surface of the maximum flood in the tan by the formula previously given; and c = a constant of the v or 3 feet according to circumstances—that is, the vertical l the top of the dam above the top of the pitching.

The wasteway of the Ashti dam consists of a channel havin width of 800 feet excavated through a saddle in the high ridg tuting the western boundary of the tank. The bed of this which is excavated in rock, is level for a mean length of a feet and then falls away, with a slope of 1 in 100, toward t Torrent, into which the flood waters are discharged, and thus another valley distinct from that draining the tank. The d capacity of this wasteway is 48,000 second-feet, which will water to rise 7 feet above its sill, or within 5 feet of the top of The discharge capacity of the wasteway was calculated as fo

L=width of channel=800 feet.

d_2=the depth of water in the channel=3.5 feet.

The surface slope of the channel being 1 in 100, the mean is as follows:

$$v=92.26\sqrt{\frac{h}{l}\times d_2}=17.25 \text{ feet per second}$$

and the corresponding discharge is 48,300 second-feet. Th water in the tank necessary to cause a discharge of this vo determined by the formula

$$D=C_d\,L\,d_2\sqrt{2gd}+\tfrac{2}{3}C_d\,L\,d\sqrt{2gd}$$

where d_2 is the depth of the channel and the constant C=75

The Ashti tank was designed as a minor productive work, outlay on which to the end of 1901 amounted to $278,000. nues from irrigation in that year amounted to $1,780 and revenues to $2,040. The working expenses during the s amounted to $14,500. This excess expenditure, however, w due to additional works. There was earned, in fact, a ne of 1.46 per cent on the capital outlay.

TANK DAMS.

General Mullins in his Manual of Irrigation[a] lays down some different rules for the top width and various dimensions of an earthen dam from those above quoted from Mr. Burke. He says that the top width of an earth dam should not be less than 4½ feet anywhere, and while that width will suffice for the ends of dams of comparatively shallow tanks, the width at the deeper part of these should be increased to 6 feet. From 9 to 12 feet will be a proper top width for larger dams, and for very large ones one-fourth of the depth of the water is the prescribed minimum for the deeper parts and 8 feet at the ends. The top of the dam, the upstream slope of which is revetted, should always slope toward the rear edge, so that the rainfall may flow off down the rear slope and not on the revetment, with the risk of washing out the back of the latter; 1 on 16 for earth and 1 on 24 for gravel will be suitable grades for this top slope. The grade of the exterior or front slope will depend upon the description of protection against wash to be provided, revetted slopes ranging from one-third 1½ on 1; for shingle, slopes of 1 on 2 or 2½ are suitable. The gradient for the exterior or rear slope will vary according to the nature of the soil from 1 on 1½, which is the steepest allowable, to 1 on 3.

In southern India at or near the center of the dam is considered the best position for a puddle wall. It is of primary importance that the wall should not crack during the considerable periods of each year that the tanks are either dry or the water in them is at a low level. The material most used for puddle walls in Madras is clay of the description used for tile making. It is well tempered and a puddle made not too wet. Any excess of moisture beyond that needed to allow of the entire wall being worked into a homogeneous mass increases the risks arising from settlement. The top width given to puddle walls, whatever their height, is about 2 feet, and the top level is made from 1 to 2 feet below the level of the top of the dam. Batters of from one 1 to 8 on 1 are given to the faces of the puddle wall. The thickness of the wall at the base, that is, at the ground level, is usually found by the formula $2+\frac{2h}{b}$ in which h is the height from the ground to the top of the wall and b is the batter. The foundation of the wall is frequently of concrete down to an adequate depth below the ground surface, viz, to 1 foot at least in clay or impervious soil and to 4 feet in more or less pervious soils. The cross section of the foundation trench is made as wide at top as the base of the puddle wall and somewhat narrower at the bottom, being cut with side slopes of 3 or 4 on 1. In revetting water slopes of dams a suitable backing of small stone and gravel is always placed beneath the revetment of uncemented stone.

---

a Mullins, Lieut. Gen. J., Irrigation Manual, E. & F. N. Spon, London and New York, 1890.

In designing the surplus weirs or wasteways the quant
to be gotten rid of must first be ascertained. The len
required is usually ascertained in Madras either from t
calculation with the formula for weirs:

$$D = L \times \tfrac{2}{3} cd \sqrt{2gd}$$
$$= L \times \tfrac{2}{3} c \times 8.02 \sqrt{d^3}$$

which, with $c = .6075$ (a value applicable to very many tank
comes $D = 3.25\, L \sqrt{d^3}$, in which D is equal to the discharg
feet; c is a coefficient, the value of which varies with the
weir, but seldom exceeds 0.65; d is the maximum dept
water to be allowed to pass over the weir, and $2g$ is a
representing the force of gravity.

As of interest, showing how even earthen dams whi
structed in a most substantial manner may slip or subside
unexpected cause, the following is a description of the
occurred in the Ekruk and Ashti dams. The full-supply
Ekruk dam has a thickness of 91 feet, and at the maxi
lated flood level its thickness is 41 feet. From the date of
tion in 1869 until September, 1872, the dam was perfectly
in good order, but in that month excessive rain fell all ov
of the country in which the dam is situated. From 9 to
rain were gaged at different places in the catchment ar
the 19th and 23d. The water on this occasion rose to 6 f
crest of the waste weir and at the same time three slips
the rear slope of the dam. Colonel Fife, the chief engineer,
ited the tank and reported that the slope of the embank
the earth had slipped or been washed down was not verti
about 45°, and this for about 10 feet only, after which it bec
No leakage whatever was observed through the dam. I
accident dry stone drains had been constructed at an ang
rear slope to carry off the rains and prevent scouring of t
ments; it was thought that these drains at the site of t
become choked or had sunk, owing to the saturated cond
soil, and had thus allowed the water to accumulate and es
ing away the earth below. These drains on the slope were
done away with, the dam was carefully made up to its
tion, berms were constructed to weight the toe of the dam
of the slips, and surface drains were cut to carry off the sli
under the dam.

No further accident occurred to this dam until the sum
when another slip took place, coincident with heavy rain o
ment basin. The position of this slip was directly in con
one of the slips of 1872, the rear half of the dam having
age length of 188 feet subsided vertically about 8 feet.
of the embankment was founded principally on black soi

become saturated, resembling a pulpy mass, and had been forced upward by the pressure of the dam. To remedy this a dry stone retaining and draining wall was constructed at the toe of the dam at the side of the slope. This wall was sunk 8 feet into the ground and was 10 feet wide at the bed; cross drains were also cut to drain this in the direction of the creek below the bank, and a counterfort or berm 45 feet wide and 10 feet in height was raised on the toe of the embankment to counteract, by its weight, the tendency to bulge upward.

Early in November, 1883, owing to excessive rains, the water in the Ashti tank rose 1 foot over the crest of the wasteweir; shortly after a small horizontal crack about 40 feet in length was observed in the pitching on the front slope, and it was immediately repaired by removing the stones, tamping the bank, and relaying the pitching. About a week later a crack 3 inches wide and 4 inches deep was found in the rear of the slope. This crack had a horizontal length of about 60 feet and ran down the slope to a level of about 10 feet below full-supply mark. It was at once repaired, but on the following day it reopened, when a settlement at the top of the dam was observed. From this time for several days the top continued to subside and the ground at the toe of the dam to bulge upward. Equilibrium was not established until a week later. The total settlement of the top of the dam amounted to 16 feet, bringing it 4 feet below the full-supply level of the tank; the pitched slope, however, remained intact up to about 4 feet above this level.

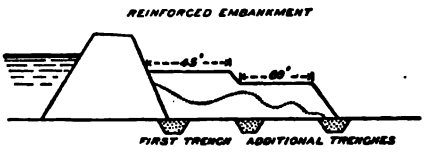


FIG. 60.—Ashti dam slips.

The causes of the slips resemble in a measure those of the slips at the Ekruk tank. A considerable length of the dam is founded on a clay soil, with nodules of dirty lime in it, and generally contains a quantity of alkali which causes it to become semifluid when soaked with water. It is probable that at the site of the slope the excavation for the puddle trench had not been made quite deep enough to prevent leakage of water under it. The length of the slipped portion at the top was 155 feet. The dam at this point is 44.3 feet in height and at the time of the accident the water was standing 31.7 feet deep at this point.

The permanent corrective measures adopted after the cessation of the movement were the digging of a trench at the toe of the rear slope which was filled with bowlders and broken stone (fig. 60), as was done for the Ekruk dam, heaping the excavated material and other earth on to the bulged-up ground to counterbalance the lifting action, remaking the dam to its original section, and adding earth and broken stone to give additional weight to the rear slope. The drainage trench

combined systems of storage works and irrigating
two other combined systems which differ from th
characteristics and should be described as of peculi
the Palar anicut system in Madras, whereby the wa
River is furnished to a number of tanks by means
supply channels and is stored in these tanks until
of irrigation. The other is the Zhara Karez ir
Beluchistan, by which a number of small detache
the bottom lands adjacent to the Machka Torrent
nel intercepting the subsurface flow and by chan
torrent to the tanks during portions of the year wh
water in the stream.

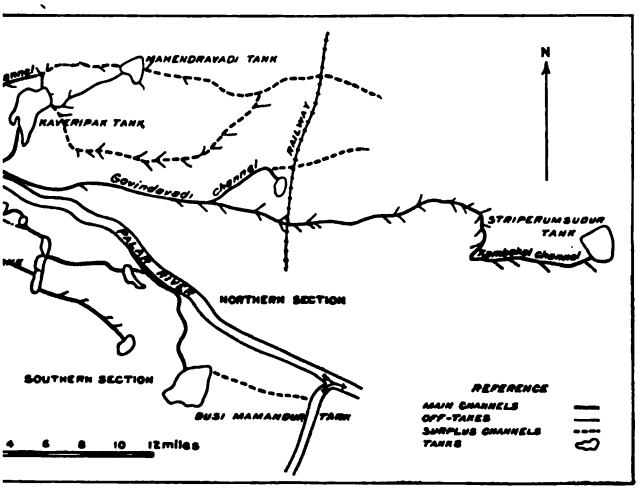
PALAR ANICUT SYSTEM.

The Palar anicut or wier was originally designed
supply to old channels which fed a series of old
situated on the Palar River, 4 miles below the tow
a catchment basin above it of 3,974 square miles,
discharge from which is 25,000 second-feet. Anic
which means literally wier, and the Palar anicut
sion wier constructed across the Palar River where
on both banks of the river into the supply canals
the wier.

The irrigation which commenced in 1853 with an
of wet-weather irrigation and 700 acres of dry-
extended until 1882, when there was an area of 6

The weir was breached for a length of 1,015 feet by the ober, 1874, previous to its final reconstruction. The he north are the Mahendravadi channel supplying the ame name, and the main channel which branches into iannels, one at 3 miles from the head and the other at the weir. From this last channel other branches are ch terminate in various tanks. On the south side are s. The project has not realized the anticipations origin- ecause the supply in the river bed was overestimated, there were considerable defects in the channels them- nally laid out.

records show that on an average there are 273.7 days ich no water is registered. The northern channels



61.—Palar anicut system, showing main channels and offtakes.

supply when there is 5½ feet on the sill of the weir under ie southern channels not until there is 7 feet on that side. River rises on the Mysore plateau and runs into the ocean of about 220 miles. There is extensive irrigation from river channels, which are chiefly provided with masonry weir supplying the system here described is built at the and fifty-second mile, and is situated about 4 miles ious town and fort of Arcot. The drainage basin of the point is about 3,974 square miles, the maximum flood ut 25,000 second-feet, and the maximum depth of flow the weir 6.75 feet, as before stated.

tle or no direct irrigation from the main or branch chan- ost every case the water is first let into the tanks in ored. These are frequently of large size, as the Kaveri- the northern and the Dusi Mamandur on the southern rigate 5,870 and 3,050 acres, respectively. As at pres-

ent constructed, the system contains on the northern side 127 irrigating 38,260 acres, or about 300 acres per tank; and 74 irrigating 14,750 acres, or nearly 200 acres per tank, on the sou side. Only a p of these, howeve filled by river many of them rec large supplies fr local drainage, is conveyed to th various channels

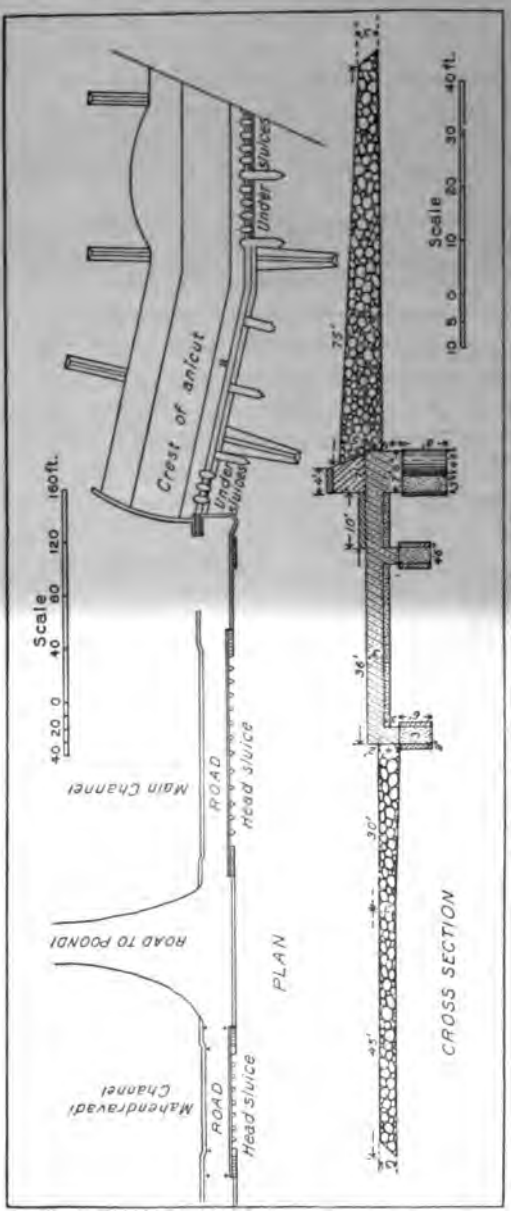
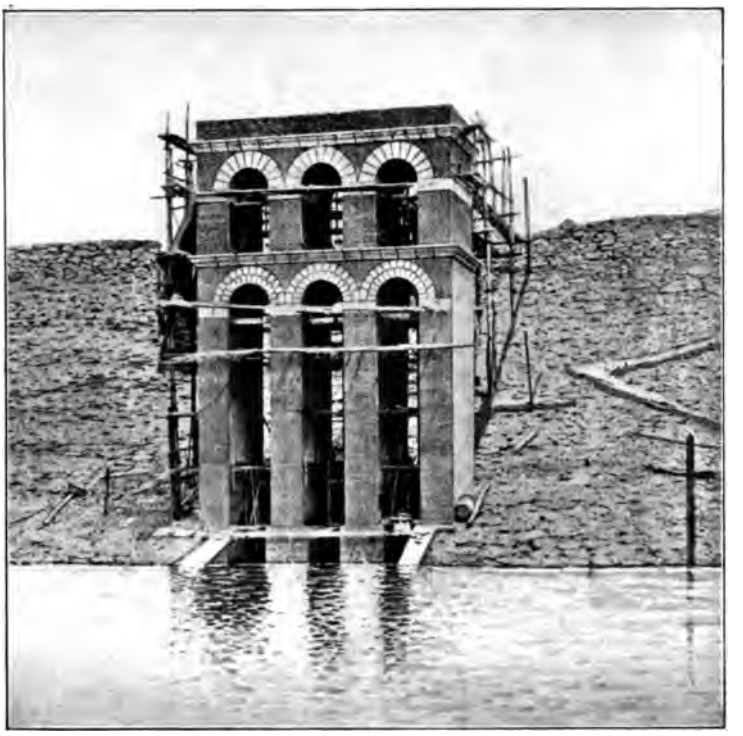
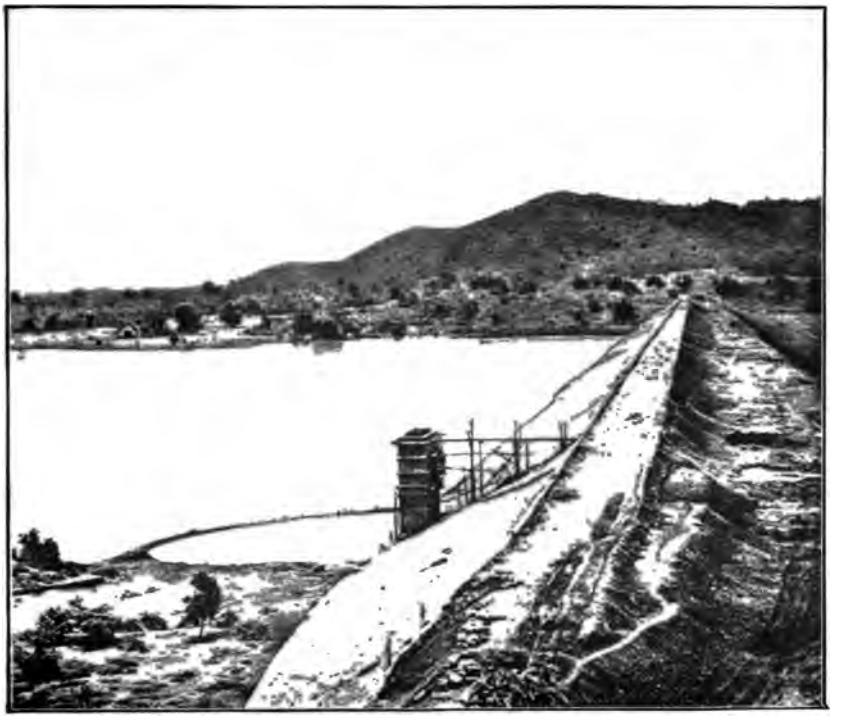


FIG. 62.—Plan and cross section of Palar anicut system.

The Palar Riv extremely objecti one for the supp large irrigation s The northern sluices receive supply only du average of 22.6 each year, as th are 1½ feet abo sills of the n sluices. The c capacity of the n main canal is n than 3,140 secon It is 215 feet wi ries 4 feet in d water, and has a 3 feet per mile southern main 113 feet wide, c feet in depth of and has a fall o per mile with charge of 2,300 feet. Combinin results with the of days during the water sup available it will that the northern nel carries 140,0 feet during the period of full supply and the southern c 65,000 acre-feet. These are assumed as the volumes which det the area capable of being irrigated.



A. RUSSELLKONDA HEAD SLUICE.



B. RUSSELLKONDA DAM.

RUSSELLKONDA TANK, RUSHIKULYA PROJECT.

The Rushikulya irrigation system consists of two canals drawn from the Rivers Mahánadi and Rushikulya, which are tapped by anicuts built at the heads of those canals, and the supply further supplemented from two reservoirs, the Russellkonda and Suradá. The Russellkonda is formed by damming up a valley in the basin of the Mahánadi and supplying it by an anicut and channel from the Gulleri River, one of the affluents of the Mahánadi. The Suradá reservoir is constructed across the Pathama River, one of the affluents of the Rushikulya. The length of the Mahánadi canal is 19 miles, while that of the Rushikulya to the Chatrapur-Berhampur road is 57 miles.

The dam (Pl. XXVII, *B*) is entirely of earth, carefully worked in layers with a puddle wall through the center and carried up to within 25 feet of the top of the bund, as it was considered essential to continue it above a point where there was less than 15 feet of water pressure at F. T. L. The front slope is carried up on an average of two-thirds of the height of the dam at a slope of 2:1 and from that point at a slope of 1:1, and revetted with stone-pitching 2½ inches in thickness. The rear slope is 2½:1 up to the same height and then is brought up in the ratio of 1½:1. The rear slope is turfed throughout with a berm varying from 10 to 50 feet wide at the point where the break in ratio of slope occurs. The settlement throughout has been perfectly uniform, and no slips or dangerous percolation have as yet occurred. The maximum height of the dam is 75 feet and depth of water 58 feet. Its contents at F. T. L. will be 2,295 millions of cubic feet, and it can be supplied from the Gulleri River in thirty-eight days.

The head-sluice (Pl. XXVII, *A*) is built of table-molded bricks and ashlar string courses and ashlar vents. The vents, three in number, are closed by cast-steel shutters worked from a platform by ordinary screw gearing with ball-friction bearings, and can be raised without difficulty by six men against the maximum head of 42 feet of water. The anicut is of the usual form adopted in the Madras Presidency, with a clear drop wall 6 feet in height, with an upper masonry apron, and longitudinal retaining walls, all founded on wells, with a packed rough stone and an adjustable loose-stone apron below.

The Mahánadi canal head-sluice and scouring sluices in juxtaposition thereto are built of random rubble and pointed with surki mortar. The sluices are fitted with shutters and screw gearings. The Janamalli anicut, built at the rear of the Rushikulya canal, across the river of the same name, consists of a main body wall and a sloping talus of rough stone, with one longitudinal retaining wall and an adjustable loose-stone apron below. The water from the Mahánadi canal, being passed into the Rushikulya, is arrested by the anicut and diverted through the Rushikulya canal head-sluices, twelve in num-

ber. The Godahallow aqueduct, consisting of 15 arches across the river of that name, is 40 feet wide and will carry a maximum depth of 8 feet of water. The side walls are of random rubble in surki mortar and the arches of brick in surki mortar. A depth not exceeding 3 feet has been passed over it, sufficient for present requirements of the irrigation below.

ZHARA KAREZ IRRIGATION PROJECT.

This scheme proposes to store in detached small tanks the water supply which runs in the Machka Torrent for a month or so in spring. The site of the scheme and the catchment basin of the torrent are in

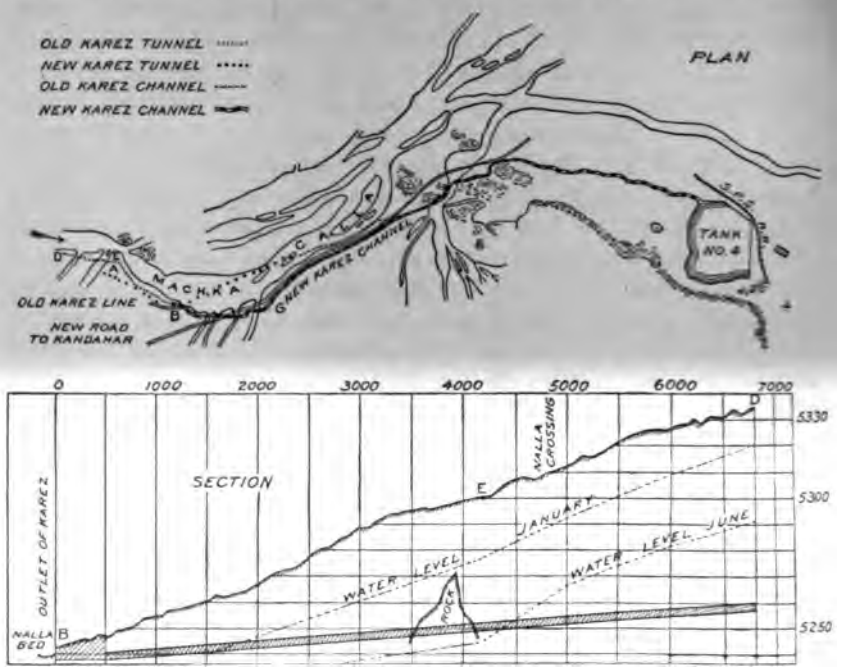


FIG. 63.—Zhara Karez irrigation project, Beluchistan.

Beluchistan, in the neighborhood of Khojak Pass. In the winter a good snow generally falls on the hills and after melting filtrates through the shale and runs off in springs lower down. The bed of the torrent has a slope seldom less than 1 in 70 where it leaves the hills; a short distance lower down its bed deepens until it is about 30 feet below the surface of the plain. There is no possible site for a large reservoir and accordingly five small sites for tanks were selected. About six of the last twenty years there has been no winter supply in the stream. In summer there are occasional heavy showers, but the floods last but a few hours and little or none of their water can be stored. The tanks are to be filled by small water courses leading from the stream (fig. 63) and the water will then be utilized about the 1st of May in giving a

final watering to rain-sown wheat crops, as the spring rains are generally sufficient up to that time. When empty, the beds of the tanks will be utilized for small crops without irrigation. There are no distributing canals, as in no case is anything larger than a large private water channel necessary.

The tanks are all on a comparatively small scale, the maximum depth having been fixed at 12 or 14 feet. As no clay was available for making puddle, the top of the bank is 3 feet above the full supply level, and the inside slopes are either pitched with bowlders or planted with willows. The outlet sluice is a simple concrete wall with numerous holes 0.8 of a foot in diameter placed at various depths and closed by wooden plugs, which can be opened by hand from a movable ladder resting on top of the well. From the bottom of the well a culvert leads under the embankment with stop walls on the outside. There is scarcely any local drainage to any of the tanks, and hence no large escapes are necessary. As a precaution the top of the well is only carried up to the full supply level.

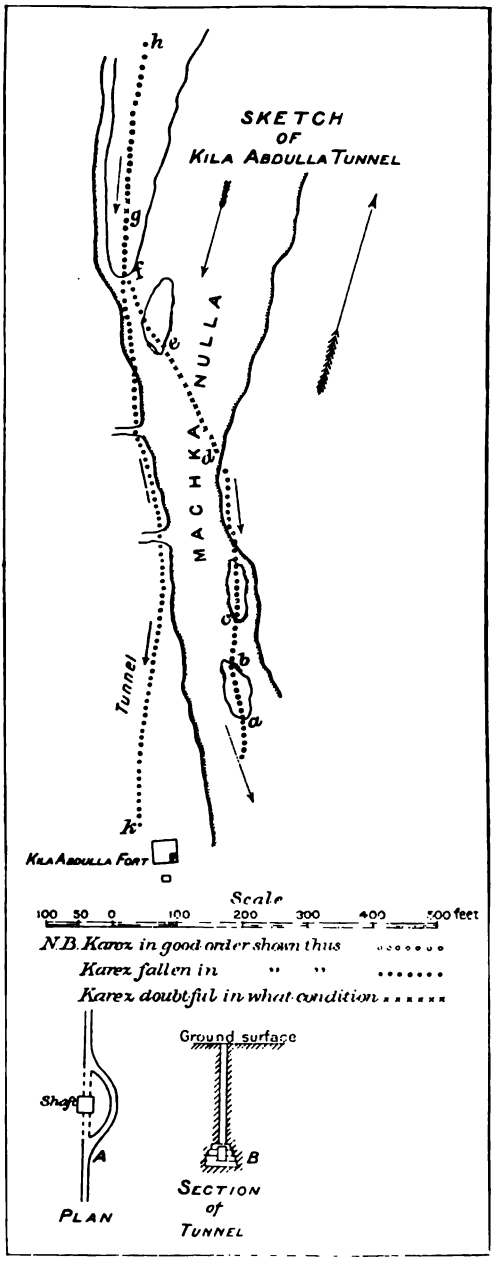


FIG. 64.—Machka Nulla Karez.

The total amount of water available in the tanks for purposes of irrigation, after deducting losses by absorption, will be 1,550 acre-feet, and this is estimated to be sufficient to irrigate 2,570 acres; from which deduct about 30 per

cent for the bad years, when there will scarcely be any rainfall, the average acreage irrigable during the dry season will be about 1,800. To this may be added 200 acres of wet-weather crop sown in the tank bed. The total cost of constructing this system of tanks is estimated as being $2,800, and the total revenue is estimated to be 75 cents per acre, from which it will be seen that the scheme as a whole is estimated to pay 4 per cent.

In 1887 the construction of tank No. 4 was authorized, in addition to which a tunnel 5,800 feet in length was authorized to be constructed under the stream channel, with shafts at every 50 feet and curved passages around each shaft, with a short piece of open excavation 900 feet in length. From the last shaft to the surface of the ground is an open channel 2,500 feet in length to connect the tunnel with tank No. 4. The object of this tunnel is to intercept the subsurface drainage and thus insure a supply to the tank, which will immensely increase its utility as an irrigating reservoir.

For many generations there has been an old tunnel at this site, which frequently fell into decay and disuse until again cleaned out. Its alignment is shown in the accompanying illustration (fig. 63). About the year 1883 a portion came to grief through a flood finding its way down some of the shafts, and since then it was not used until its repair was proposed in 1887. By the latter part of 1887, 40 shafts and a half mile of the tunnel had been completed. The water-bearing stratum had been reached and a discharge of half a second-foot obtained. The old tunnel worked with a constant discharge of 9 second-feet for forty years. As the new channel is better located and in better soil, it is estimated to give at least as good results as the old one did. The slope of the tunnel is 3 in 1,000, the sections 3 by 1.7 feet, or, say, 5 square feet, which with a mean velocity of 1.8 feet per second will give a maximum discharge of 9 second-feet.

The estimated cost of this work is nearly $4,000. The rates paid were 10 cents per lineal foot in depth of shaft and 20 cents per lineal foot of horizontal tunnel, the excavation being entirely in earth. The returns estimated are as follows: Discharge, 9 second-feet; area irrigable by 1 second-foot or duty, 150 acres; rate per acre, $1.50; gross revenue, about $1,600. The maintenance charges will amount to practically nothing.

CHAPTER IX.

RIVER TRAINING AND LAND RECLAMATION.

RIVER CONSERVANCY.

In connection with all irrigation works maintained on the great plains and deltaic rivers of India, river training and improvement works must be constructed in order to maintain the stream in the channel which will cause it to do least injury to the various irrigation works. During seasons of flood the branches of these great rivers change, as does the Missouri River, tearing into enormous tracts of the surrounding country, and they would, if not properly guided, destroy great portions of the canal and remove hundreds of acres of valuable irrigable land. In addition to this destruction of property, they cause severe inundations during the times of flood, which destroy valuable crops and property.

These inundations, when of small magnitude and confined within reasonable limits, do little harm and even much good may result from them. They do not increase the healthiness of the neighborhood, but the silt deposited by the water tends to fertilize the land, thus enabling richer crops to be produced with much less trouble. Autumn crops which lie along the edge of inundations of this minor class are usually defended by earth embankments, which are often miles in length. These embankments are of no great height or solidity, and are merely built in comparatively shallow water to save the crops, but inundations of greater magnitude, where the waters attain great force and extend through the heart of a large district, destroying houses, bridges, and canals, and washing away land, are of another kind. In providing a remedy for this class of inundation the engineer must possess great skill and patience.

The planting of Nanel grass, which is a long, coarse variety of water grass, when the plantations are properly arranged and progressively made, gives one of the best means of reclaiming parts of the river which are beyond the proper boundaries of the waterway. This grass thrives in the streams of India, the cost is much less than that of any other treatment, and the reclamation is performed by the action of the river itself, by the deposition of silt due to the reduction of the current, so that water highly charged with silt at the upper end of a plantation is often found to issue from the lower end with little or no discoloration.

Above and below the head-works of the Lower Ganges canal at

Narora the river flows through a low bottom land which is limited at some distance back from its banks by a bluff about 60 feet in height. It was immediately found necessary to construct training works to prevent the stream from cutting into this bottom land, thus turning the end of the weir from above, or perhaps cutting into the bank and

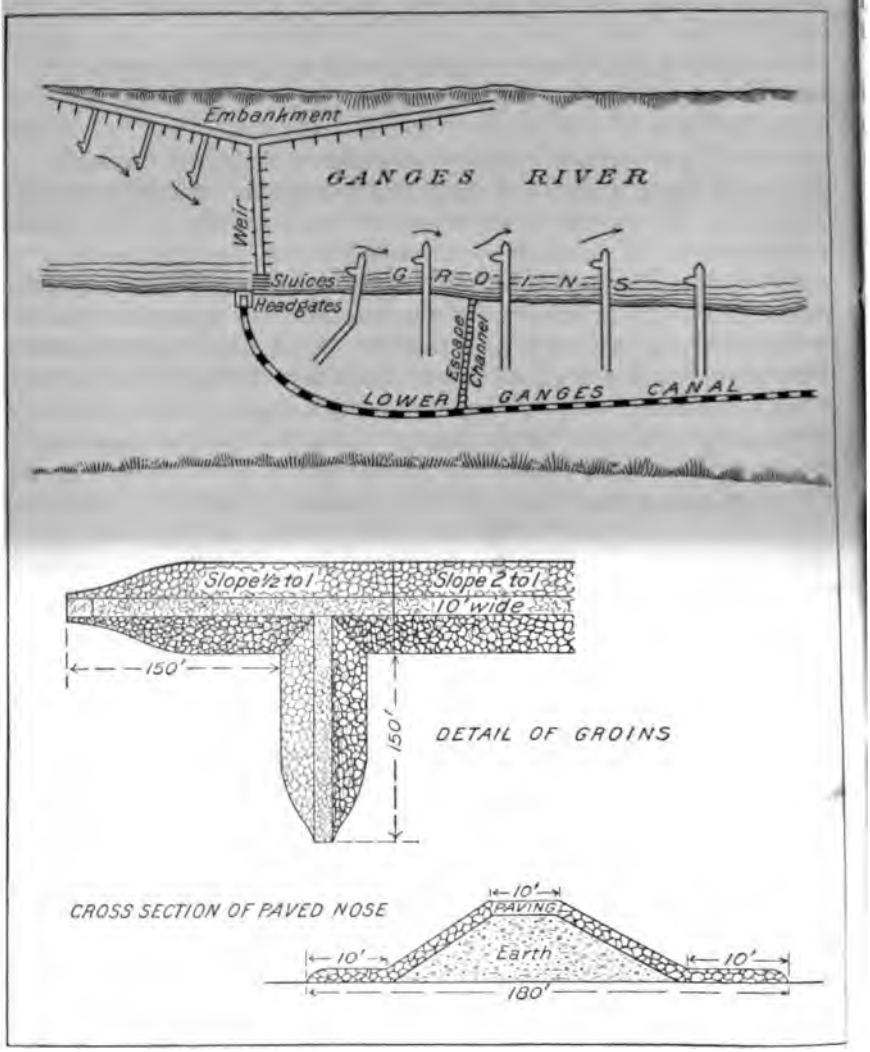


FIG. 65.—Training works, Lower Ganges canal, Narora.

destroying the canal itself below the weir. These training works extend 4 miles above the head of the canal and about 15 miles below it (fig. 65). The works consist on the upstream side of the weir of a long earthen embankment from which other embankments of earth jut out at right angles to the course of the stream, thus forcing

the current over to the other side. At first these embankments, or, as they are called, "groins," were constructed so as to point downstream, making an angle of perhaps 45° with the course of the current, but it was found that they did not work well. They have since been realigned so that they project at right angles to the stream, and are placed exactly one-half mile apart, and they are found to perform their work excellently. As yet none have failed.

These groins are often very long, some as much as 2½ miles in length. They are simply straight embankments of earth 10 feet wide on top, with slopes of 1 on 2. The last 150 feet at the end of the groin, or the nose, as it is called, is paved with heavy stones to a depth of 2 to 3 feet, and at 50 feet from the end a spur 50 feet in length, similarly paved, is run at right angles to the line of the bank, pointing upstream.

At Hardwar, the head of the Ganges canal, the river runs between high, steep gravel and rock banks, on which it is able to make no impression by erosion, and training works are therefore unnecessary below the weir. Above it, however, the bed of the stream is so broad and is divided into so many channels during the dry season that it is necessary to construct extensive training works to keep open a permanent channel, known as the Hardwar Channel, which passes in front of the head of the canal and supplies it with water. The fall of the river above the head-works is 8 feet per mile, and at low-water stage it has a velocity of 6 feet per second. This velocity is many times greater in periods of flood. As shown in the plan of the head-works at Hardwar (fig. 18), the training works consist of bars sunk into the river channels to prevent the retrogression of grades and the consequent destruction of the dams; of weirs to turn the water into the Hardwar channel; of rectangular groins projecting into the river similarly to those on the Lower Ganges canal, in order to keep the water in the Hardwar Channel; and, lastly, of embankments of bowlders to protect the weaker portions of the river banks. Great difficulty has been encountered in maintaining the integrity of the noses of the groins, as the heavy floods undercut these and cause them to fall into the river. Great concrete blocks 3 by 5 by 2 feet in dimensions, weighing 2 tons each, are first dropped into the river as a foundation for the groins. When these reach the water surface the end of the groin is built up of loose concrete blocks in a regular manner, and the remainder of the groins, constructed of bowlders, is run back from this end. As the floods wash away the foundation blocks the built-up portion of the groin falls in and replaces them, furnishing a new foundation, and this in turn is itself replaced. Thus in the course of a few years the bed of the river becomes filled to such a depth with these blocks that further destruction ceases to take place, and the groins will then stand for many years.

At the head of the Agra canal, at Okhla, the weir which diverts the

water into the canal head is, as before described, constructed of l hand-placed rocks, and to preserve its integrity, and at the same t to train the course of the Jumna River toward its right bank against the head of the canal, groins of a peculiar form of const tion are run out at right angles to the line of the weir (fig. 66) parallel to the course of the river. These works are known as "

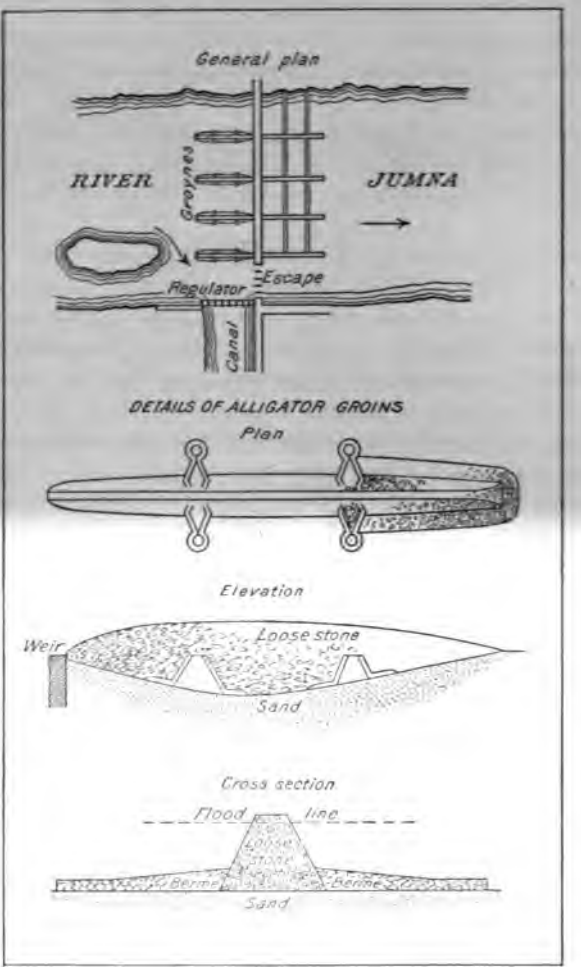


FIG. 66. Training works, Agra canal, Okhla.

gator groins" from their peculiar form, which somewhat resei that of an alligator. They are constructed of loose stones du into the river without any foundation on which to rest, the tops sides of the groins being carefully hand laid, so as to give them and integrity. The floods annually wash away portions of groins at first and during low season they have to be repaired like those on the Ganges canal, in the course of a few years the

rock underlying the groin becomes so great that repairs rapidly diminish in amount or entirely cease to be necessary. The tendency of the water in the river is to flow in a direction nearly parallel to the face of the weir and toward the under sluices, thus destroying the weir. These groins cause portions of the water to flow over the weir at right angles to it, thus doing it no injury. Other portions of the stream are forced over against an island, indicated in the accompanying plate, and tend to remove it, at the same time furnishing a supply for the canal head.

Spoonbills, or legs, are run out from the groins at right angles, and a berm 10 feet in width is built around the end of the groin and the spoonbill. The portion annually destroyed is the berm. This falls to the river, leaving the main body of the groin intact. The top of the groin is built at an elevation of 1 foot above highest flood level, and the top of the spoonbill is 7 feet below flood level.

LAND RECLAMATION.

A good deal has been done in some of the more swampy portions of India toward the reclamation of swamps and their conversion into valuable agricultural properties. This reclamation has been most extensively practiced in what are known as "duns," especially because it increases the healthfulness of these regions by substituting for marshes dry land under cultivation. Swamp reclamation has been practiced in various parts of the United States and the methods are essentially the same in character as those employed for the same purpose in India.

In reclaiming marsh lands, such as those in the "duns," it has been considered usually essential first to make a complete survey of the region in order to discover the slope of the lands in the direction in which cuttings for the purpose of drainage can best be made. The lines on which the drainage cuts shall be made having been laid down, it remains simply to so design these cuts that they shall command the gross area of the swamp in the most economical manner, and shall completely remove the water from it. Some of these drainage works have added thousands of acres of valuable land to the agricultural regions, and have changed fever-stricken neighborhoods to healthy cultivated fields where fevers are scarcely known. The financial returns from some of these works have been even greater and more satisfactory than those from irrigation works proper, and reclamation works of this character are now prosecuted in India with as much zest as is the construction of canals or storage works.

INDEX.

A. Page.

Aboo, canal built by 89
Aboo, Mount, altitude of 41
rainfall at 44
Absorption of water by soil, notes on 68–74
Acreage of irrigated land, statement showing 35–36, 57–58, 60
Acre-foot, definition of 67, 158
Aden tanks, Arabia, description of 23
plate showing 22
Agra, rainfall at 44
Agra canal, aqueduct over 23
course of 95–96
crops under 96
drainage reservoir on 141–142
examination of 22–23
expenses of 96
head-works of 22, 95, 125, 130
history of 95
Kushuk Falls on, cross section of 142
revenue derived from 58
training works for 223–224
water rate charged on lands under 96
water supply of, source of 22
weir at head of 113, 120
Agricultural results of irrigation, statistics showing 58–62
Akbar, Emperor, irrigation works built by 47
Ali Murdan, Delhi canal constructed by 47
Ali Torrent, aqueduct at 23
Aligarh, Ganges canal bifurcation at 92–93
rainfall at 44
inspection made at 19
Alignment of canals, considerations determining 107
Alkali, production of, by irrigation 64–66
removal of, by irrigation 64–65
Alkali Commission, report of, extracts from 65–66
Allahabad, topography and agriculture near 16
visit to 18–19
Ameen, duties of 52
Altitudes of Himalaya Mountains 39–41
American irrigation compared with Indian, cost of works for each 60–62
Anderson, Colonel, cited on silt accumulation in canals 106
quoted on velocities of canals 106
Anicut. *See* Dam *and* Weir.
Aqueducts, descriptions of 20, 23, 92, 138–144, 172, 218
plans and sections of 139, 143, 144, 145, 149, 171
views of 102, 138, 140, 168
Arabia, Aden tanks in, plate showing 22

Page.

Areas cultivated and irrigated, extent of 35, 57–60
Arrah canal, duty of water under 103
expenses of 103
size and course of 16, 102
Asafnagar Falls, Ganges canal, view of, plate showing 134
Ashti dam, description of 208–210
landslip at 212, 213
profile of 208
waterway of 210
Ashti tank, description of 208–210
data concerning 204
history of 206
Ashti tank and canals, map of 207
Assam, area, topography, and other features of 41
rainfall in 43, 44
tea cultivation in 37–38
Atgoan, trip to 14
Auckland, Lord, Ganges canal sanctioned by 90

B.

Bagge, Lieutenant, Betwa canal project investigated by 173
Baker, Maj. W. E., cited on serviceableness of Western Jumna canal 32
report made by, on canal from Sutlej River 97
work on Ganges canal done by 90
Baker, Maj. W. E., and others of committee, cited on causes of sickness along Delhi canal 63
Baldwin, Latham, cited on circulation of water through soil 151–152
Bari Doab canal, area irrigated under 99
Chuki Torrent diversion on 137–138
cost of 99
cross section of, dimensions of 104
discharge of 99
duty of water along 72
falls on 135–136
head-works of, regulating sluices at 125
history of 99
rapids on 136
revenue derived from 99
sources of supply of 99
Barley, acreage and value of 60
season for growing 38
Baroda, tank on Surwa River above 23
Barrage du Nil, description of 82
examination of 21
Beale, H., aid by 13, 90
Begari canal, data concerning .....

Page.
Distributaries, heads of, location and features of ... 146, 148
losses of water in, by percolation ... 71
masonry outlet for, plan and section showing ... 156
mileage of ... 58, 59
Distributing head, Mutha canal, plans of ... 148
Ditches. *See* Distributaries.
Dixon, Colonel, cited on results of construction of Mairwara tank embankments ... 201
irrigation works constructed by ... 200, 201, 202
Doab Canal, duty of water along ... 67
Dora Baltea River, Italy, aqueduct across, examination of ... 24
Double cropping, notes on ... 66
Douleshwaram, irrigation works at ... 83
Drainage works, description of ... 137–144
Dredges, Soane canals, use of ... 18
Duhlia, rainfall in ... 44
Dunds, use of, as head-works for inundation canals ... 78–79
Duns, canals in, revenue derived from ... 96–97
crops grown in ... 97
irrigation in ... 97
location of ... 40
reclamation of ... 225
Duty of water, Arrah canal ... 103
Bari Doab canal ... 72
Bombay ... 67
data concerning ... 67–74
definition of ... 67
Ganges canal ... 93
Lower Ganges canal ... 95
measurement of, unit for ... 158
Sidhnai canal ... 100
Sirhind canal ... 99
Soane canals ... 103
Duvur tank, work at ... 85
Dyer, Colonel, cited on silt deposition in Western Jumna canal ... 106–107

E.

East India Company, irrigation works constructed by ... 48
Eastern Jumna canal, construction of ... 47
head-works of ... 99
irrigated area under ... 73
revenue derived from ... 58
Ekruk dam, landslip at ... 212–213
Ekruk tank, crops irrigated from ... 205
data concerning ... 204
description of ... 205–206
irrigation from, crops raised by ... 205
plan and sections of ... 204
Ellenborough, Lord, reference to ... 90
Engineering work, organization and administration of ... 51
Engineers, recruitment of ... 51
Escapes, descriptions of ... 132–134
Etawah, branch of Ganges canal, course of ... 92–93
Evaporation, data concerning ... 69, 73
diagrams illustrating ... 69
Everest, Mount, elevation of ... 39
Excavation, cost of ... 195–196
Expenditures on irrigation works, statistics concerning ... 9, 57–58

F.

Page.
Falls and rapids, discussion of ... 134–137
views of ... 136
Famine Commission (Indian), report of, extracts from ... 33–34
Farini canal, Italy, reference to ... 24
Farms or fields irrigated, sizes of ... 55
Feroze, Emperor, irrigation work done under ... 47, 97, 99
Fertilizer, use of ... 38
Fields irrigated, sizes of ... 55
Fife, Colonel, cited on landslip at Ekruk dam ... 212
Mutha canal scheme proposed by ... 160
Nira canal project promoted by ... 163
Fife, Lake, dam at, description of ... 162
description of ... 12, 160
statistics concerning ... 159
Financial results of irrigation, statistics showing ... 58–62
Floats for stream gauging, use of ... 74
Floods in rivers, precautions against ... 221
Fodder crops, acreage and value of, 1900–1901 ... 60
Forest reservations, area of ... 43
Forests, effect of removal of ... 45–46
preservation of, work done for ... 45
revenue derived from ... 45
Forrest, James, aid by ... 11
Foundations for masonry work, description of ... 190–192
Fruits, production of ... 37
Fuleli canal, data concerning ... 80

G.

Gadanamathi River, discharge of ... 62
Galton, Douglas, cited on effects of irrigation on health in India ... 64
Ganges canal, aqueducts along ... 21, 92, 140–141
Asafnagar Falls on, description of ... 134–135
view of ... 134
cost of ... 78, 93
crops irrigated from ... 93
defects of ... 93–94
discharge of ... 93
dimensions of ... 100
distributaries of, mileage of ... 93
duty of water along ... 68–69, 93
expenses of ... 58, 93
Gopalpur bifurcation of, plate showing ... 92
head-works, description of ... 126–127
figure showing ... 127
plan of ... 91, 127
regulating works at ... 125–126
health conditions along, provisions concerning ... 63–64
history of ... 89–90
land irrigable and irrigated from ... 93
Nadrai aqueduct on, figures showing construction of ... 145
ogee falls on ... 134–135
plans of ... 91, 146–147
profile of, Hardwar to Roorkee ... 8
regulating gates of, figure showing ... 125
revenue derived from ... 58, 93

Page.

Ganges canal, Rutmoo level crossing on, description of ... 142-143
view of ... 149
slope of ... 106
Solani aqueduct on ... 139
views on, plates showing ... 92, 120, 134, 142
water supplied by, amount of ... 93
weir at head of ... 116-117, 121
Ganges canal, Lower. *See* Lower Ganges canal.
Ghar canal, data concerning ... 80
Ganges River, area drained by and course of ... 40
breadth, fall, and discharge of ... 42
dams (temporary) on ... 118-119
discharge of ... 66, 94
navigation on, as affected by irrigation ... 66
weir at Hardwar on ... 116-117
Gangetan Plain, features of ... 16, 40
Gates in dams, descriptions and figures of ... 83, 116, 119-130, 162, 165, 166-169, 177, 178-181, 185
Geology of India, general features of ... 42-43
Ghauts, features of ... 41, 43
western, rainfall in ... 44
Goa, temperature at ... 44-45
Godahallow aqueduct, description of ... 218
Godavari canal, data concerning ... 87
Godavari River, breadth, fall, and discharge of ... 42
canal system in delta of ... 83
source, drainage basin, and deltas of ... 41
Gohana tank, data concerning ... 201
Good, W., cited on Kali Nadi aqueduct ... 140
Gopalpur bifurcation, Ganges canal, plate showing ... 92
Gordon, W. B., cited on well sinking for masonry foundations ... 132
Governor-general of India, powers vested in ... 49
Grains, lands suitable for growing ... 38
Greathed, Colonel, Betwa canal project examined by ... 173
opinion of, concerning weir for Betwa canal ...
Groins of training works, descriptions of ... 221-222
figures showing ... 222, 223
Gulleri River, irrigation from ... 217

H.

Haig, F. T., cited on revenue to be expected from the Soane canals ... 103
Hamirpur branch of Betwa canal, description of ... 174
dimensions of ... 174
Harbinge, Lord, Ganges canal project aided by ... 90
Hardwar, Ganges River at, discharge of ... 92
Ganges River at, features of ... 92
training works above ... 222, 224
inspection made at ... 21
weir at head of Ganges canal near ... 116-117
Hastings, Marquis of, reference to ... 47
Head-works, descriptions of ... 82-86, 94, 95, 107-109, 120, 125, 175-176

Page.

Head-works, location of, considerations determining ... 88-89, 107-109
plans and views of ... 127, 168, 169, 175, 183, 207
See also Dams, Training works, Sluices, Weirs.
Health, conditions of, along Delhi canal, facts bearing on ... [illegible]
Heywood, quoted on discharge of principal rivers ...
Hilgard, E. W., reference to ...
Hill, A., quoted on masonry construction of Bhatgar dam ...
quoted on scouring sluices ...
Hill, Col. H., mention of ...
Himalayas, altitudes of mountains and passes in ... 39-[illegible]
drainage of ... 39-[illegible]
foothills of, altitude and topography of ... 40
geology of ... 42-43
origin of name ... 39
rainfall in ... 44
Sierra Nevada compared with ... 39
Hindun River, dam projected across ... 89-90
diversion of ... 22
irrigation canal from ... 96
Holdings of land, statistics concerning ... 55

Home, Col. F. J., reference to ... 20
Betwa canal project investigated by ... 173
cited on Mairwara tank embankments ... 202
Horn, Mr., reference to ... 17
Hughes, W. C., aid by ... 11
Hurron Torrent, siphon for, across Sirhind canal ... 98

I.

India, administration and legislation of irrigation works in ... 48-55
area of and area cultivated and irrigated in ... 9-10, 35, 57-60
climate of ... 7
crops in, value of ... 10
cultivated area in ... 9
geology of ... 42-43
irrigated area in ... 9-10, 35, 57-60
irrigation in, administration of ... 48-55
expenditures for ... 9
value and necessity of ... 29-34
works on (list) ... 25-28
irrigation works in, cost of, compared with probable cost of similar works in United States ... 60-62
legislation and administration of irrigation works in ... 48-55
map of ... 11
population of ... 9
railway travel in ... 15
topography of central part of ... 15
Indigo, acreage of, under cultivation ... 95, 93, 96
duty of water for ... 73
irrigation of, from Agra canal ... 96
production of ... 37
Indus River, course and drainage area of ... 39-40, 80
flood level and discharge of ... 42, 80

Page.
Indus River Valley, inundation canals in . 78-81
precipitation in . 31
Inglis, W. A., aid by . 17
computations regarding Arrah canal made by . 103
Inundation canals, cost of . 80-81
data concerning . 78-81
expenses of . 80-81
revenue from . 80, 81
Irrigable area, acreage of . 57-58, 59
Irrigated area, acreage of . 35-36, 57-58, 60
Irrigated crops, acreage, character and value of . 36
Irrigated fields, sizes of . 55
Irrigated lands, revenue derived from . 35, 58
Irrigation, agricultural results of . 58, 62
development of, method of promoting . 50
expenditures for . 33-34, 58, 80
extent and character of . 57-58
history of . 50
laws relating to . 52-54
objections to . 63-66
time required for, per acre . 73
value and necessity of . 29-34
water required for, amount of, per unit of area . 73
wells used for . 75-77
works on, list of . 25-28
Irrigation canals. *See* Canals.
Irrigation engineers, mode of recruitment of . 51
Irrigation works, administration of . 48-55
agricultural results of . 58-62
area served and to be served by . 58, 60
classes of . 56-57
conditions governing construction of . 157-158
cost of . 9, 32-34, 48, 57-62, 80-81, 99, 172
durability of . 195
expenses of . 32-34, 57-62, 80-81, 96, 103
financial results of . 33-34, 58-62
history of . 47-48
income from . 32-35, 58-62, 96
legislation concerning . 52-54
officers engaged in administration of . 51
value of, statistics showing . 33-34
two classes of, productive and protective . 29-30
Italy, irrigation canals in, examination of . 24-25
Ivrea canal, Italy, examination of . 24, 25

J.

Jamrao canal, data concerning . 80
Janamalli anicut, description of . 217
Jehan, Shah, canals constructed under . 47, 99
Jewhar Torren, siphon for beneath Nira canal plan and sections of . 171
Jeypur, astronomical observatories at . 23
rainfall at . 44
Jhelum canal, data concerning . 81
Jumna canal, Eastern, construction of . 47
head-works of . 99
irrigated area under . 73
revenue derived from . 32, 58
value of . 31-32

Page.
Jumna canal, Western, cost of . 9
crops raised under in 1838, value of . 32
cross section of, dimensions of . 10
expenses of . 9
first construction of . 47
head-works of . 9
irrigated area under . 74
revenue derived from . 9
silt deposition in . 16-17
Jumna canals, earliest one constructed . 47
head-works of . 9
regulating gates at . 15, 18
property saved by, value of . 32
Jumna River, old canal deriving water from . 47
irrigation canals from . 8, 9
training works on, description of . 22-23, 25
figure showing . 23
Jute, production and export of . 37
Juwaja tank, data concerning . 91

K.

Kabra tank, data concerning . 93
Kalee Kuncur tank, data concerning . 93
Kali Nadi, aqueduct for Lower Ganges canal over . 30, 131-132, 139-140
canal taken from . 9
Kanigiri reservoir, escape from, plate showing . 9
head sluices of, plate showing . 8
work at . 6
Kao Nulla siphon aqueduct beneath Soane canal, examination of . 17
description of . 102, 143-144
figure showing . 144
Kathund branch of Betwa canal, dimensions of . 171
Khoord, dam site at . 13
Khundwa, rainfall at . 44
Khutowli escape, Ganges canal, features of . 19
King, M., aid by . 21
King, Dr. W., aid by . 16
Kistna anicut, river in moderate flood at, plate showing . 84
Kistna canal, data concerning . 87
Kistna River, breadth, fall, and discharge of . 42
canal system in delta of . 83-86
source, drainage basin, and delta of . 41
Kolevoy tank, features of . 90
Kurnool canal, data concerning . 87
Kurra aqueduct, Nira canal, view of . 168
Kurra River, aqueduct for Nira canal over . 172
Kushuk Falls, Agra canal, cross section of . 142

L.

Labor and material, cost of . 31, 193-198
Lahore, trip to . 90
Lake, Sir Atwell, reference to . 84
Land irrigated, acreage of . 60
Land reclamation, method of . 25
Land rentals, collection of, method of . 49, 50, 52-55

Page.
, statistics concerning ... 55
lams, instances of 212 214
r lifting water 75
lwin, reference to..... 14
ning irrigation, quotations
om 52-54
'. H., reference to..... 13
oncerning irrigation works,
atures of..... 52-54
,head-works of Soane canal,
signed by..... 103
r, data concerning..... 201
es canal, aqueduct for, over
ali Nadi 139-140
over 20, 131
able and irrigated from.... 94-95
.... 94
..... 94,
of 94
ater under 95
of 95
ks and river-training system
.... 20, 94
ks of, foundations for ... 130-131
ating gates at..... 128
'..... 93-94
queduct of..... 131
eir of..... 20, 112-113, 119-120, 126
lerived from..... ... . 58, 94
, absence of..... 125
works on, description of . 221-222
showing..... 222
arora on.... 20, 112-113, 119-120, 126

M.

ent, plan and section at..... 219
r tank, description of 199
and population of..... 35
vated and irrigated in 35, 57
at rates on irrigated and non-
rigated land in 32
nals in 83-85
works in, area served by .. 57
f..... 57
ption of..... .. 181-187
on of 57
ue derived from..... 57
res in 55
.... 44
.... 202, 203-204
ures in 44
ration Company, construc-
on of works by. 48
mention of 109
nal, headworks of... 217
..... 217
ver, irrigation from..... 86-87, 217
of..... 82
dir, sluices in, features of 120 121
ik embankments, cost of.... 201
erning 201-202
from 201
construction of 201-202
ns of..... 201
ge and value of, 1900-1901.... 60
infall at..... 44

Page.
Manure, use of 38
Maps of India, character of 155
Marsh lands, reclamation of . 225
Masonry, cost of 31, 196
durability of..... 195
Masonry dams, designs and construction
of..... 188-193
Materials used in construction of irriga-
tion works, cost of 196
McNeill, Col. J. M., aid by 16
Medley, Col. J. G., cited on sluiceways of
Mahannudy weir 121
Medlicott, H. B., and others of alkali com-
mission, report of, extracts
from 65 66
Merriman, Col. C. J., Ashti tank plans pre-
pared under orders of.. .... 206 207
Meteorology, features of 43-45
Mhaswad tank, data concerning. 204
Midnapore canal, Bengal, data concern-
ing 86-87
Millet, acreage and value of 60
lands suitable for growing . . 37, 38
Misau, weirs at 109
Mogul canals, construction of 47
restoration of . .. 48
Molesworth, G. L., cited on designs for
masonry dams 191
Molesworth's formula for profile of ma-
sonry dams 191, 192
Moncrieff, Col. Sir Scott, aid by . . . 24
Mooltan, rainfall at 44
temperature at 45
Mortality, rate of 35
Mortar, method of preparing . . 189 190
tests of.. .... 190 191
Mount. *See next word in name.*
Mot, figure and plate showing 74, 77
use of, for lifting water. . . . 75
Muddur weir, cross section of . . . 109, 110
Mullins, Gen. J., cited on conditions to
be considered in undertaking
the construction of irrigation
works 157
cited on dimensions of dams 211 212
formula of, for profile for masonry
dams 192
Mutha canals, bridges and head-gates of,
construction of 13
city of Poona supplied by water from. 58
cost of.. 159
distributaries on, plans of heads of . 148
duty of water along..... 67
head of. 12
history of..... 109
inspection of. 12-13
map showing location of. 161
municipal service of water by 58
revenues derived from..... 109
sickness along, causes of 64
statistics concerning 159, 160
Mutha irrigation project, description
of..... 160-163
map showing 161
Mutha River, course of, map showing . 161
source of..... 160

Page

Mutha River Valley, topography, soil, and agriculture of 12
Muthra, rainfall at 44
Muzaffargarh canal, data concerning 81
Myapur, headworks of Ganges canal at .. 119, 125-126
weir at 22, 92, 120
gates in 120
sluices in 120
Mysore, tanks in 202-203

N.

Nadrai aqueduct, foundations of 131
foundation wells for, view of 130
history of 139-140
sections of 145
Nanel grass, planting of, to reclaim riparian land 221
Narora, headworks on Lower Ganges canal at 120, 131
researches made at 19-20
training works at 222
weir at, features of 94, 112-113, 119, 126
material used for 189
plans of 116, 120
Nasregunge, researches at 16-17
Navigation of tapped rivers, effect of irrigation on 66
Navigation on irrigation canals, difficulties of 195
Negar, rainfall at 44
Nile River, irrigation works in delta of 82
Nira canal, catchment basin for 164
cost of 172
cross section of, dimensions of 104
figure showing 170
expenses of 169
head-works of, description of 169-171
plans and section of 169-170
regulating gates at 128
history of 163-164
irrigation from, time required for 73
location of, map showing 161
regulator head on, plan of 170
superpassage of, at siphon for Jewhar Torrent 171, 172
weir at head of, cross section of 170
Nira canal system, cost of 159, 172
description of 163-173
map showing 161
revenues derived from 173
source of water for 13
statistics concerning 159, 160
views showing works of 164, 168, 170
Nira River, map showing course of 161
Northwest Provinces, area cultivated and irrigated in 35
canals in 89-97
irrigation by wells in 75
area served by 58
cost of 58
extent and character of 58
revenue derived from 58
rivers of, discharge of 88
Nundyal tank, features of 200

O.

Ogee falls, use of ..... [illegible]
Oil seeds, production and use of ..... [illegible]
Okhla, Agra canal head-works at ..... [illegible]
examinations made at ..... [illegible]
training works at, description o[illegible]
plans and sections of ..... [illegible]
weir at, sluices in ..... [illegible]
Orai, visit to ..... [illegible]
Oreste, Canavotte, aid by ..... [illegible]
Orissa canals, cost of, per acre o[illegible]
served ..... [illegible]
data concerning ..... [illegible]
weir at head of, sluices in ..... [illegible]
Ottley, Major, reference to ..... [illegible]
Oudh, area cultivated and irrigat[illegible]
irrigation works in, cost of ..... [illegible]
extent of ..... [illegible]
revenue derived from ..... [illegible]

P.

Paccottah, figure and plate showi[illegible]
use of, for lifting water ..... [illegible]
Palar anicut system, data concern[illegible]
description of ..... [illegible]
map showing ..... [illegible]
plan and cross section of ..... [illegible]
weir of ..... [illegible]
Palmer, C. G., aid by ..... [illegible]
Palmer, E. C., cited on duty of w[illegible]
Bari Doab canal ..... [illegible]
Parasnath, Mount, altitude of ..... [illegible]
Paricha, Betwa canal head at ..... [illegible]
Patna, rainfall at ..... [illegible]
Patna canal, course of ..... [illegible]
Patrala Sombe, masonry dams [illegible]
struction of ..... [illegible]
Pattiala, Maharajah of, mentio[illegible]
connection with can[illegible]
Sutlej River ..... [illegible]
Pease, irrigation of, from Agra c[illegible]
Peile, J. P., and others, cited on [illegible]
irrigation works ..... [illegible]
Penner Canal, data concerning ..... [illegible]
Penner River delta, irrigation [illegible]
in ..... [illegible]
Penny, Capt. C. B., Ashti tank p[illegible]
by ..... [illegible]
Pennycuick, Major, cited on for[illegible]
profile of masonry da[illegible]
report on Periyar canal proje[illegible]
by ..... [illegible]
Peranny River, weir on ..... [illegible]
Percolation, diagrams illustratin[illegible]
losses by ..... [illegible]
observations on ..... [illegible]
Perennial canals, data concernin[illegible]
Periyar project, dam for, materia[illegible]
construction of ..... [illegible]
dam for, section of ..... [illegible]
view showing ..... [illegible]
description of ..... [illegible]
head-works for, plan of ..... [illegible]
plan of ..... [illegible]
reservoir for, capacity of ..... [illegible]
Persian wheel, figure and plate s[illegible]
use of, for lifting water ..... [illegible]

Page.

Plantain canal beds, prevention of growth of ... 105
Po River, Italy, weir across ... 24
Poona, labor prices at ... 195
storage reservoir near ... 100
tunnel for Mutha canal at ... 163
water supplied to, by Mutha canal. 58
Poorniah weir, mention of ... 109
Poppy (for opium) production of ... 37
Population of India, by provinces, table showing ... 35
total ... 9
Porter, Hon. A. G., aid by ... 24
Potatoes, production of ... 37
Precipitation. *See* Rainfall.
Provinces of India, area and population of, table showing ... 35
Pulse, acreage and value of, 1900-1901 ... 60
Puniary tank, dam of ... 199
Punjab, area and population of ... 35
area cultivated and irrigated in. 35, 58, 73
canals in ... 78, 81, 97-101
irrigation by wells in ... 75
area served by ... 58, 73
cost of ... 33, 58
extent of ... 58
revenue derived from ... 58
land rental or taxation in ... 50
land tenures in ... 55
rainfall in ... 43, 44
revenue from irrigation works in 34
rivers of, discharge of ... 88
topography of ... 80
wheat production in ... 36-37
Puthri Torrent, aqueduct over Ganges canal for ... 21, 92, 140-141

R.

Railway travel in India, features of ... 15
Rainfall, amount and distribution of ... 43-44
Ranipur Torrent, aqueduct over Ganges canal for ... 21, 92, 140-141
Rapids and falls, discussion of ... 134-136
Ravi River, irrigation canals from ... 99, 100
section of, at dam for Sidhnai canal 117
Reay, Lord, reference to ... 14
Rebsch, Mr., aid by ... 12
Reh Commission, report of, extracts from ... 65-66
Reid, H. S., and others of alkali commission, report of, extract from 65-66
Reinold, E. K., weir gate devised by, description of ... 166-169
weir gate devised by, plans and sections of ... 166, 167, 168
Reservoirs, descriptions of ... 19, 153-220
Revenue from irrigation works, amount of ... 58
mode of collecting ... 49-50
statistics concerning ... 32-34, 35, 57-58
Rice, acreage of ... 36, 37, 93
irrigation of, methods employed for 151
lands used for production of ... 37
season for growing ... 38
yield of, per acre ... 37
River conservancy, methods of ... 221-225

Page.

River flow, rate of, mode of determining 74
Rivers, breadth, fall, and discharge of, table showing 42
navigation of, as affected by water draft for irrigation ... 66
River training, methods of ... 220-224
Riverside lands, reclamation of, by planting of Nanel grass. ... 221
Road crossings over canals, bridges at, form of ... 17
Roopana weir, data concerning 201
Roorkee, aqueduct near ... 92, 130
examinations made at ... 21, 22
Rotto canal, Italy, reference to 24
Rundall, Colonel, reference to 101
Reinold, E. K., weir gate devised by 166-167, 168
Rupar, head-works of Sirhind canal near 98
Rushikulya project, description of 217-218
Russell, Scott, cited on slope of dams 210
Russellkonda dam, view of ... 216
Russellkonda head sluice, view of ... 216
Russellkonda tank, description of 217-218
Rutmoo Torrent, junction of, with Ganges canal 21, 92, 142-143
view showing ... 142
Ryatwari, land tenures of ... 55
Ryves, Major, report made by, on Periyar canal project ... 182
Ryves's formula for flood discharge from catchment basin, statement of, and coefficient for ... 156, 157

S.

Saharanpur division of Eastern Jamna canal, irrigated area in ... 73
Sakkur, flood discharge of Indus River above ... 42
Saluggia, Italy, canals near, examination of 24-25
Sangam anicut project, description of 85-86
Sankey, Maj. R. H., cited on mode of construction of old (native) head-works of canals ... 110
cited on use of tanks in Mysore 202-203
Santhia, Italy, irrigation works near, examination of ... 25
Sasoon superpassage over Sirhind canal, description of ... 141
plan and section of 149
Schuyler, Eugene, aid by ... 24
Scouring sluices, description of ... 119-124
Second-foot of water, definition of 67
irrigating power of ... 73
Sewalik Hills, geology of ... 42
Shadouf, use of, for lifting water ... 75
Shutter gates in dams, descriptions and figures of ... 83, 116, 119, 130, 162, 165, 166-169, 177, 178-181, 185
Sickness along Delhi canal, causes of 63
Sidhnai canal, area irrigable under ... 100
character of ... 97
cost of ... 101
course of ... 100
crops irrigated from ... 100
discharge of ... 101
duty of water under ... 100

Page.
Sidhnai canal, head-works of 100-101
head-works of, regulating gates at 129-130
history of 97, 100
revenue derived from 59, 101
section of river in line of dam on 117
water rate under 101
weir at head of, plans and section of 116
Sidhnai weir, plan and section of 116
sluice gates of, features of 123, 124
figure showing form of 123
Sierra Nevada, comparison of Himalayas with 39
Silt, deposition of, in canals, prevention of 105, 106
Simla, temperature at 45
Sind, area cultivated and irrigated in 31, 35, 57
inundation canals in 78-81
irrigation in, cost of 57
irrigation works in, cost of 57
revenue derived from 31, 35, 57
rainfall in 31, 43, 44, 98
Sirhind canal, aqueducts along 98
area irrigable and irrigated by 61, 98
cost of 61, 99
course of 98
crops irrigated from, acreage and value of 60
cross section of, dimensions of 104
discharge of 98
duty of water under 99
head-works of 98
history of 97-98
length of 98, 99
map showing 98
revenue from 99
Sasoon superpassage over, description of 141
plan and section of 149
torrents crossing 98, 141, 149
water rate under 99
Siswan Torrent, volume of 98
Skipworth, Col. G. T., reference to 18, 21
Slope of banks and beds of canals, data concerning 104-107
Sluiceways, features of 119-130
Sluices, scouring, description of 119-124
plan of 177
Smith, Col. R. Baird, cited on dimensions of Mairwari tank, embankments, and piers 200
cited on time required after completion to make irrigation works profitable 33
cited on value of Eastern Jumna canal 31-32
quoted on effect of irrigation on the navigation of tapped rivers 66
quoted on mode of construction of weirs 111
report made by, on projected course of Sirhind canal 97
Periyar canal project submitted by 182, 183
Soane canals, aqueducts along 102, 138-139, 143-144
area irrigated from 103
boats on, description of 17-18

Page.
Soane canals, cost of ..... [illegible]
cross section of main western branch of ..... [illegible]
distributaries along, surplusage of ..... [illegible]
dredges used on ..... [illegible]
duty of water under ..... [illegible]
examination of ..... [illegible]
expenses of ..... [illegible]
falls on ..... [illegible]
head-works of, description of ..... [illegible]
foundation wells at ..... [illegible]
gates at ..... [illegible]
history of ..... [illegible]
inspection of ..... [illegible]
Kao Nulla siphon aqueduct beneath main western branch of ..... [illegible]
length of ..... [illegible]
locks of ..... [illegible]
map showing courses of ..... [illegible]
passenger traffic on ..... [illegible]
revenue derived from ..... [illegible]
traffic on ..... [illegible]
trees on banks of ..... [illegible]
velocity of flow of water in ..... [illegible]
water rate under ..... [illegible]
weir at head of, description of ..... [illegible]
plan of ..... [illegible]
shutter on, figure showing form of ..... [illegible]
sluices of, figure showing ..... [illegible]
features of ..... [illegible]
sluiceways in ..... [illegible]
Soane River, canals taking water from ..... [illegible]
course of ..... [illegible]
discharge of ..... [illegible]
weir across ..... [illegible]
Soil, absorption of water by, notes on ..... [illegible]
circulation of water in, experiments made to show ..... [illegible]
composition of ..... [illegible]
fertility of ..... [illegible]
Solani aqueduct, examination of ..... [illegible]
foundations for ..... [illegible]
cross section of ..... [illegible]
description of ..... [illegible]
view of, plate showing ..... [illegible]
Sone canals. *See* Soane.
Sooroody River, utilization of, for irrigation purposes ..... [illegible]
Sorghum, production of ..... [illegible]
Sospizio, Carlos, aid by ..... [illegible]
Sotas, definition of term ..... [illegible]
use of, as head-works for inundation canals ..... [illegible]
Spices, production of ..... [illegible]
States, native, area and population of ..... [illegible]
Stevenson's formula, statement of ..... [illegible]
Stoney free-roller gate at tunnel head, description of ..... [illegible]
Storage of water, cost of ..... [illegible]
Storage works, descriptions of ..... [illegible]
Strachey, Gen. Richard, Betwa canal proposed by ..... [illegible]
cited on time required after completion to make irrigation works profitable ..... [illegible]

Page.

Richard, Ganges canal de-
reported by 91, 93
Richard, and others, cited
alue of irrigation works .. 33-34
r, mode of gaging 74
vsage and value of ... 36, 37, 60, 93
er for 67, 73
f, methods employed for .. 151
district for growing 37, 38
lata concerning 80
and others, cited on value
rigation works 33-34
oir, location of 217
nal lines, character of 89
ank on 23
lata concerning 81
irrigation canal taken
n 97-98
reclamation of 225

T.

istration of 49
er, east branch of, canal
m 85
of 198, 205, 206, 207, 209, 211-214
ater storage, descriptions
..... 153-220
and reservoir, description
..... 14, 15, 187-188
..... 188
sections of 186, 188
s of 40
ions concerning 51, 149-150
l rentals, mode of collect-
g 49, 50, 52, 55
on of 36, 37, 38
, notes on 43, 44-45
Robert, cited on tanks in
ysore 202
er, penalty for 53
ollege of Civil Engineering,
sit to 22
aqueduct, Soane canal, de-
ription of 17, 138-139
owing 102
. T., cited on violent floods
ne to forest removal 46
d. H. R., aid by 16
of, income derived from 45
oduction of 36, 37
, features of 39-43
rks for rivers, descriptions
..... 220-224
..... 121
canals, species of 18
e, Col., cited on silt deposits
inundation canals 79
, temperatures at 44
weir at 109
j. Hector, Tonsa reservoir
roject promoted by 187
ainfall at 44
ture at 44

U.

vinces and Oudh, area and
opulation of 35

Page.

United States, irrigation works in, cost of,
compared with cost of works
in India 60-62

V.

V weirs, condition favoring construction
of 150
Vaigai River Valley, irrigation of, proj-
ect for 181-187
Vanupshahr branch of Ganges canal,
course of 93
Vedacunay channel, mention of 186
Veeranum tank, dam of 199
Vegetables, production of 37, 60
Velocities of canals, discussion of 105-106
Velocity of streams, mode of measuring 74
Viceroy of India, powers vested in 49
Vindhaya Mountains, drainage of 41
Vir, dam at, features of 13-14, 189
head-works of Nira canal at, descrip-
tion of 128, 169-171
view of 168
Vir River, view showing 170
Virainum tank, data concerning 204
Vonder Horst, W. P., aid by 19

W.

Wargaon River, aqueduct for Nira canal
over 172
Water, circulation of, in soils 151-152
distribution of, rules and regulations
for 51-52
duty of, data concerning 67-74
unit of measurement for 158
methods of applying 150-152
storage of, cost of 158
theft of, penalty for 53
Water rates or rents, act fixing 53
act regulating levying of 52
collection of, method of 49, 50, 52, 55
statements of 31, 57, 96
Weeds in canal beds, growth of, preven-
tion of 105
Wegmann, Edward, cited on design and
construction of masonry dams. 191
Weir gate, plan and sections of 166, 167, 168
Weirs, descriptions of 13, 14, 15, 19,
20, 22, 82-86, 94, 95, 109-124, 175-176,
183-184, 188-193, 201, 205, 207-215
form and construction of 109-119, 188-193
formula for discharge over 103
open and closed, comparison of 110
plans and sections of 109, 112, 114, 115,
116, 118, 121, 122, 123, 126, 165, 167, 170, 175-
179, 182, 183, 186, 187, 192, 198, 208, 213, 216
views of 84, 114,
116, 120, 122, 164, 168, 170, 182, 186, 188, 216
Well foundations, descriptions of 130-132
Wells, irrigation by 56, 75-77, 96
Western Jumna canal, cost of 99
crops raised under, in 1838, value of 32
cross section of, dimensions of 104
expenses of 99
first construction of 47
head-works of 99
irrigated area under 74
revenue derived from 99
silt deposition in 106-107

Page.
Wheat, acreage and value of 36, 60, 93, 96
cost of irrigating 73
duty of water for 67, 72
season for growing 38
yield of, per acre 36-37
Whiting, J. E., surveys for Nira canal made by 164
Williamson, Mr., aid by 17
Wilson, W. J., reference to 21
Winds, direction and character of 43
Works for irrigation, classes of 56-57

Y.

Page
Yule, Lieut. H., and others, cited on causes of sickness along Delhi canal. 47

Z.

Zabita Khan, reference to 47
Zemindars, functions of 50
land holdings of 55
Zhara Karez irrigation project, description of 218-220
map and section of 218
Zilahdars, duties of 52

O

Water-Supply and Irrigation Paper No. 88 Series M, General Hydrographic Investigations, 6

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE PASSAIC FLOOD OF 1902

BY

GEORGE BUELL HOLLISTER

AND

MARSHALL ORA LEIGHTON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1903

CONTENTS.

	Page.
itroduction	9
escription of Passaic Basin	9
The Highland area	10
The central basin	11
The lower valley	13
ributaries of the Passaic River	15
Saddle River	15
Ramapo River	15
Wanaque River	16
Pequanac River	16
Rockaway River	17
Whippany River	17
Upper Passaic River	17
Summary	18
low of Passaic River	19
he flood of 1902	30
Precipitation in the Passaic Valley	31
Gage heights	34
Flood flow of Highland tributaries	36
Flood flow at Little Falls	39
General flood-flow statistics in Highland tributaries	41
Submerged lands in central basin	42
Flood flow at Dundee dam	43
Flood below Dundee dam	44
Flood discharge of Saddle River	45
High-water marks in lower valley	46
Losses caused by the flood	48
Comparison with previous floods	51
Summary	52
Conclusions	53

ILLUSTRATIONS.

		Page.
ATE I.	*A*, Railroad bridge at Passaic Bridge; *B*, Passaic Falls at Paterson, showing gorge	9
II.	Drainage area of Passaic River	10
III.	Part of flooded area in central basin near Fairfield	12
IV.	*A*, Dam at Little Falls; *B*, Passaic Falls at Paterson	16
V.	*A*, Little Falls gorge at low water; *B*, Little Falls gorge at high water	20
VI.	*A*, Falls, Pompton Lake; *B*, Little Falls gorge, looking under Morris Canal viaduct, high water	24
VII.	*A*, Rockaway River at Boonton; *B*, Dam at Dundee	30
VIII.	*A*, Measurement station at Stanley on Passaic River; *B*, Measurement station at Whippany on Whippany River	34
IX.	*A*, Measurement station on Rockaway River near Boonton; *B*, Macopin dam	38
X.	*A*, Gaging station No. 1, on Wanaque River at Pompton; *B*, Gaging station No. 2, on Wanaque River at Pompton	42
XI.	Map of flooded area in central basin	In pocket.
XII.	*A*, Dam on Pequanac near Pompton; *B*, Submerged flat lands at Singac	44
XIII.	*A*, Flooded area on Great Pierce Meadows; *B*, Flood at Two Bridges	46
XIV.	*A*, Flooded farmhouse in central basin; *B*, Flooded farm lands in central basin	48
XV.	*A*, Wallington during the flood; *B*, Failure of bridge at Passaic	50
G. 1.	Cross sections of Passaic Valley from Clifton to Newark	14
2.	Profile of Passaic River and tributaries	18
3.	Discharge of Passaic River at Two Bridges, 1902	28
4.	Discharge of Pompton River at Two Bridges, 1902	29
5.	Gage readings of Little Falls and Dundee dam	35
6.	Plan of Beattie's dam, Little Falls	36
7.	Flow curves at Little Falls	40
8.	Discharge curves at Little Falls and Highland tributaries	40
9.	Flood curve, Dundee dam	42
10.	Comparative flow curves, Dundee dam and Little Falls	43
11.	Profile of flood crest, Passaic to Belleville	47

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., March 30, 1903.

R: I have the honor to transmit herewith a manuscript by George Iollister and Marshall O. Leighton, relating to a serious flood in Passaic River basin in northern New Jersey in February and ch, 1902, and recommend its publication in the series of Water-ply and Irrigation Papers.

ie region affected by the flood, although a limited area, contains, oximately, one-third of the population of the entire State. Owing s proximity to the city of New York and to its natural advantages of water frontage and water powers, it contains not only many attract-residential suburbs, but also important commercial and manufac-ng centers. The vested capital and community interests are large, it is therefore desirable that the occurrence and progress of t floods in the drainage area be thoroughly understood. This stigation into the most disastrous flood ever known in the Passaic ey is of timely interest to all classes of citizens dwelling on low-s subject to floods.

Very respectfully,

F. H. NEWELL,
Hydrographer.

on. CHARLES D. WALCOTT,
Director, United States Geological Survey.

A. RAILROAD BRIDGE AT PASSAIC BRIDGE.

B. [illegible]

THE PASSAIC FLOOD OF 1902.

By G. B. Hollister and M. O. Leighton.

INTRODUCTION.

Late in February and early in March, 1902, there occured upon the drainage basin of the Passaic River in northeastern New Jersey the most disastrous flood in the history of the region. Not only was the discharge the largest recorded, but the flood was the most destructive to life and property in the settlements ever known along the valley.

In the following pages it is proposed to outline the history of this flood, describe the conditions under which it occurred, give the estimated volume of its discharge, and indicate as well as possible the nature and extent of the damage resulting from it.

The data and information embodied in the following report were obtained by personal observation while the flood was in progress and after it had subsided and from various water companies, manufacturers, and residents of the flooded areas. Acknowledgments are especially due to Mr. J. H. Cook, of Paterson, engineer for the Society for the Establishment of Useful Manufactures; to Mr. M. R. Sherred, engineer of the water department of the Newark board of public works; to Mr. R. M. Watson, of Wise & Watson, engineers of Passaic; to Mr. C. C. Vermeule, from whose valuable report on the water supply of New Jersey much data have been taken regarding the physical condition of the watersheds, and to others whose help or suggestions have been of value.

As the region under discussion, though comparatively restricted, is an important one owing to its dense population and rapidly increasing industrial development, and as the physical and physiographic conditions governing high-water stages on the Passaic watershed are peculiar, it is deemed necessary for a full understanding of the present flood to describe briefly their most important features.

DESCRIPTION OF PASSAIC BASIN.

The Passaic River is the most important stream in the State of New Jersey. Its drainage basin covers 949.1 square miles, about 818 of which are in the northeastern portion of the State of New Jersey, while

132 are in the State of New York. On or near its banks are located the cities of Paterson, Passaic, Newark, Orange, East Orange, and Jersey City, the population of which combined with that of adjacent towns and boroughs equals over 500,000, or about one-third the population of the State of New Jersey. The quantity of sewage discharged from this district, with its great population, centered in the lower part of the drainage area, is extraordinary, and the industries carried on in the different communities contribute enormous amounts of manfacturing refuse, all of which is turned into the stream. The results of this wholesale deposit of filth are that for the last 20 miles of its course the river presents one of the most aggravated cases of pollution to be found in the United States.[a]

The water powers of the Passaic were among the first used in the country. The Society for Establishing Useful Manufactures was formed in 1791, for the purpose of developing the large power existing at the Great Falls of the Passaic in the city of Paterson (Pl. I, *B*). Other powers of less extent are found and improved at Pompton, Boonton, Little Falls, Dundee, and elsewhere on the drainage area.

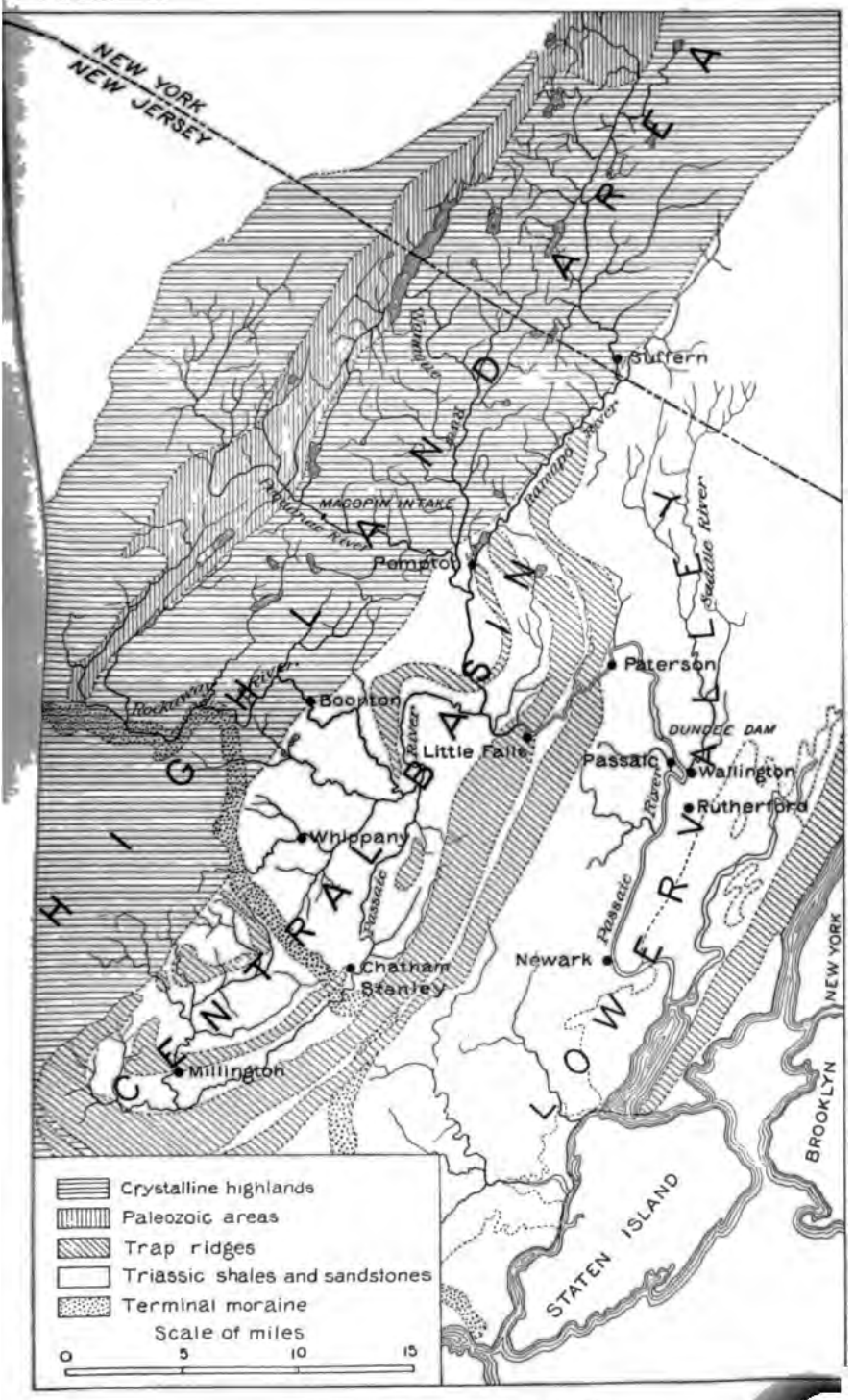
The water of the river is, however, of greatest value for municipal supply. It is already largely used for this purpose, and the demands of a rapidly growing population in the cities of northern New Jersey require that a proportionately greater amount shall be set aside from year to year.

The drainage area, as seen from Pl. II, falls naturally into three broad topographic divisions, viz, the Highland area, the central basin, and the lower valley.

THE HIGHLAND AREA.

The Highland area is the main gathering ground of the tributaries, whose united catchment basins cover 510 square miles or 53 per cent of the entire drainage area. It is a mountainous region composed of granitic and crytalline rocks which extend in a belt running northeasterly through northern New Jersey into New York State, with a width in New Jersey of from 15 to 20 miles. The region has a general altitude of from 1,000 to 1,500 feet above sea level, and represents the remnant of an old and much dissected plateau. Owing to intense metamorphism and folding of the rocks and to subsequent erosion, the highlands lie in ridges which follow a generally northeast-southwest trend. These ridges are transversely trenched by the the main arteries of the tributaries in steep-sided valleys whose bottoms lie from 300 to 600 feet below the crests. The most important tributaries which occupy this region are the Ramapo, Wanaque, Pequanac, Rockaway, Whippany, and a small portion of the upper waters of the Passaic proper. Upon it are also a number of lakes and artificial reservoirs, the latter built by water companies, which afford considerable storage.

[a] See Water-Supply and Irrigation Paper No. 72.



DRAINAGE AREA OF PASSAIC RIVER.

132 are in the State of New York. On or near its banks are located the cities of Paterson, Passaic, Newark, Orange, East Orange, and Jersey City, the population of which combined with that of adjacent towns and boroughs equals over 500,000, or about one-third the population of the State of New Jersey. The quantity of sewage discharged from this district, with its great population, centered in the lower part of the drainage area, is extraordinary, and the industries carried on in the different communities contribute enormous amounts of manfacturing refuse, all of which is turned into the stream. The results of this wholesale deposit of filth are that for the last 20 miles of its course the river presents one of the most aggravated cases of pollution to be found in the United States.[a]

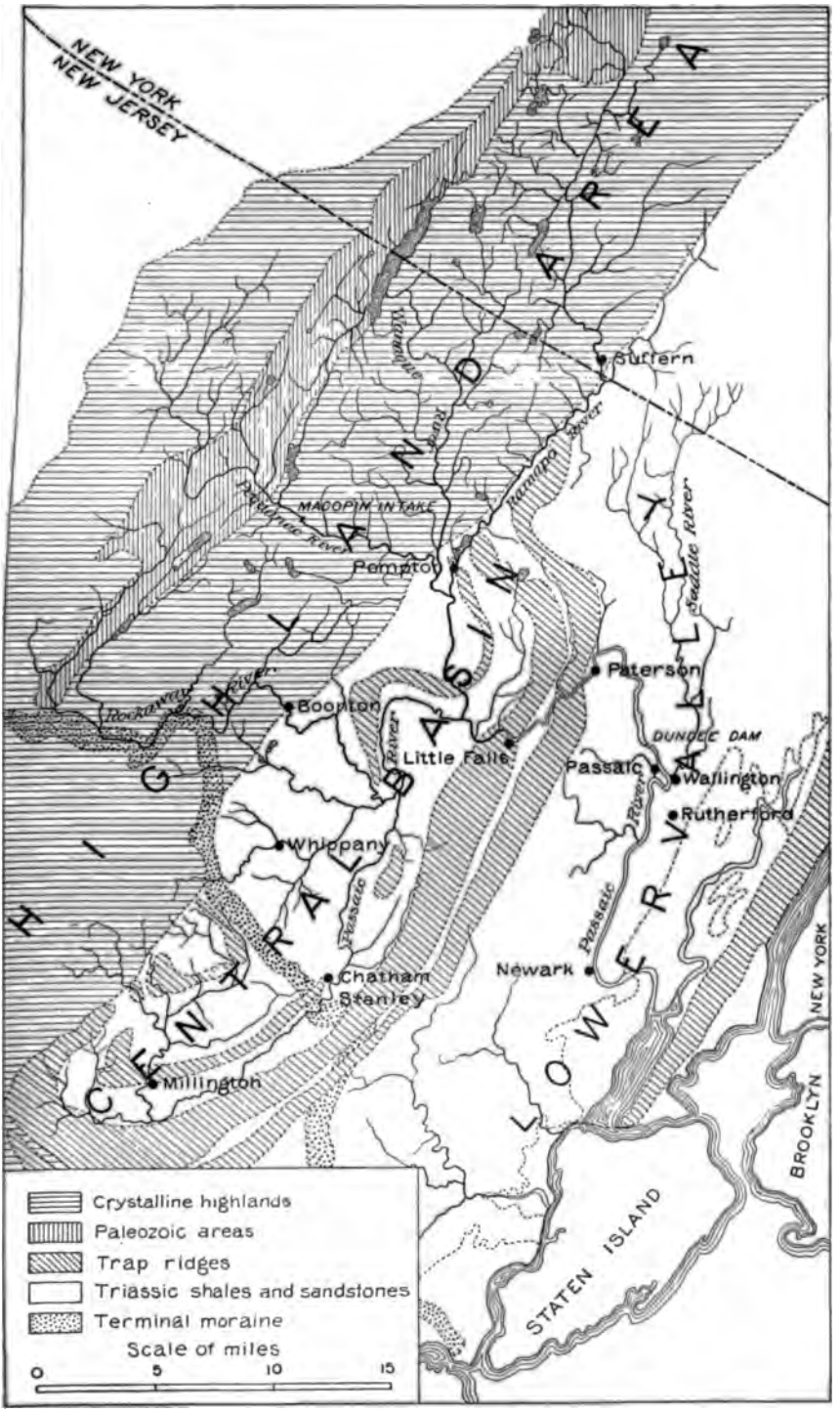
The water powers of the Passaic were among the first used in the country. The Society for Establishing Useful Manufactures was formed in 1791, for the purpose of developing the large power existing at the Great Falls of the Passaic in the city of Paterson (Pl. I, *B*). Other powers of less extent are found and improved at Pompton, Boonton, Little Falls, Dundee, and elsewhere on the drainage area.

The water of the river is, however, of greatest value for municipal supply. It is already largely used for this purpose, and the demands of a rapidly growing population in the cities of northern New Jersey require that a proportionately greater amount shall be set aside from year to year.

The drainage area, as seen from Pl. II, falls naturally into three broad topographic divisions, viz, the Highland area, the central basin, and the lower valley.

THE HIGHLAND AREA.

The Highland area is the main gathering ground of the tributaries, whose united catchment basins cover 510 square miles or 53 per cent of the entire drainage area. It is a mountainous region composed of granitic and crytalline rocks which extend in a belt running northeasterly through northern New Jersey into New York State, with a width in New Jersey of from 15 to 20 miles. The region has a general altitude of from 1,000 to 1,500 feet above sea level, and represents the remnant of an old and much dissected plateau. Owing to intense metamorphism and folding of the rocks and to subsequent erosion, the highlands lie in ridges which follow a generally northeast-southwest trend. These ridges are transversely trenched by the the main arteries of the tributaries in steep-sided valleys whose bottoms lie from 300 to 600 feet below the crests. The most important tributaries which occupy this region are the Ramapo, Wanaque, Pequanac, Rockaway, Whippany, and a small portion of the upper waters of the Passaic proper. Upon it are also a number of lakes and artificial [illegible] the latter built by water companies, which afford consider-



DRAINAGE AREA OF PASSAIC RIVER.

floods. Their extent is 29,308 acres, or 17 per cent of the area of the basin. The distribution of the wet lands is as follows:[a]

Wet lands in Passaic Basin.

	Acres
On Passaic River above Chatham	14,754
On Passaic River from Chatham to Two Bridges, including Whippany and Rockaway	12,851
On Pompton River above Two Bridges	1,140
On Passaic River from Little Falls to Two Bridges	563
Total above Little Falls	29,308

It has been satisfactorily demonstrated that during and for an indefinite period after the Glacial epoch the basin was occupied by a large body of water, approximately 200 square miles in extent, which has been geologically designated as "Lake Passaic."[b] Extensive morainal deposits at the outlet of the basin near Little Falls and Paterson, with the possible assistance of masses of ice, formed the barrier which kept the waters of the lake in place. Evidence of this phase of the region's history is found in the widespread lacustrine deposits, which are responsible for the remarkable flatness of the surface over the northern half of the basin, the striking contrast of which to the surrounding mountains has already been mentioned. Further evidences of the Glacial lake stage are also found in the great marshes which have remained to the present day. Pl. III, taken from Second Mountain at Singac, looking north to west, shows the portion of the wet lands in the middle part of the central basin; it also shows the central section of the valley formerly occupied by Lake Passaic.

The Passaic River proper passes through this basin, entering it as a small stream in the southwestern portion and flowing generally northward in a meandering course until it crosses the barrier of Second Mountain at Little Falls, and First Mountain a few miles farther north, at Great Falls, Paterson. The drop in the first instance is about 40 feet, and in the second 70 feet. (See Pl. IV, *A* and *B*.)

Into this central basin the principal tributaries, with one exception, discharge their waters, and as the gradients of all of them are steep, after heavy rains they quickly pour into the flat area such a volume of water that it is unable to pass the outlet at Little Falls, and for days and even weeks large portions of the wet lands remain under water.

The terminal moraine of the great glacier, which was noticed in the Highland area, is also found in this portion of the watershed, which it crosses in a line of low and much confused hills extending from Summit to Morristown.

The central basin is an agricultural country with relatively large centers of population, the most important being Morristown, Summit,

[a] Final Report New Jersey Geological Survey, Vol. III.
[b] Kümmel, Report of the State Geologist of New Jersey, 1893.

N NEAR FAIRFIELD.

ıatham, Madison, Morris Plains, Pompton, and Whippany. The ›pulation is 120 to the square mile, and 29 per cent of the area is in rest. The East Jersey Water Company maintains a pumping station Little Falls, from which point approximately 63,000,000 gallons of ater per day are taken.

The physiographic features most affecting the hydrography of this ›rtion of the watershed are, first, the narrow gorge of the river at ttle Falls, which quickly becomes congested in times of flood (Pl. , *A* and *B*), and, second, the large expanse of the wet lands and the level-lying valley floor, which are easily submerged when the ngestion at Little Falls takes place (Pl. III).

Although the frequent flooding in the central basin works consider- ›le hardship and even loss to the farming class there located, it is ›vertheless, a feature which has a beneficial effect upon the lower ction of the valley beyond Paterson, as it provides natural storage r accumulated waters and prevents widespread floods in the thickly habited manufacturing and suburban districts in the lower valley.

THE LOWER VALLEY.

After leaving the short series of rapids, falls, and quiet stretches om Little Falls to Paterson, the river enters the lower valley through hich it flows to its mouth at Newark Bay. The drainage area of this ction to Little Falls is 178 square miles, the main stream being 29.1 iles long. Nine and one-quarter miles below Paterson it receives ; only important tributary in the lower valley, viz, Saddle River, hich has a drainage area of 60.7 square miles. Just above the outh of this stream, at Dundee, the waters of the river are held by a ım 450 feet long, whose crest is 27 feet above mean tide. For 4 iles below this dam the river has a total drop of 6 feet to Passaic, om which point 13½ miles to Newark Bay it is a narrow tidal tuary.

The right bank of the river at Passaic is a low bench and it is ›oded in times of very high water. A large portion of the manu- cturing section of the city of Passaic is located here, and most of the jury sustained by the 1902 flood was caused by the destruction of erchandise on the lower floors of the factories and warehouses. On e left bank of the stream, opposite the city of Passaic, is another w-lying area, forming a basin which was evidently occupied by the ream in earlier stages. The general level of this area lies but a few et above tide water, and is likewise subject to overflow. It is the e of the borough of Wallington, a residence district. About mid- ıy in its extent from north to south this flat is crossed by the main ıe of the Erie Railroad on an embankment of gravel and other mate- ıl. The embankment ends at the left bank of the river.

One of the important features of the lower valley is its great popu-

lation, which has been concentrated there by reason of the natural advantages of its water front on the lower Passaic, the powers at Paterson and Passaic, and the proximity to New York City. In the district, which has an area of about 60 square miles, there are over forty cities, towns, and boroughs, representing a combined population of about 4,200 per square mile. Municipal improvements which accompany the growth of population influence the drainage of the area to some extent, by reason of the construction of large areas of paved and macadamized roads which constitute "quick spilling" surfaces.

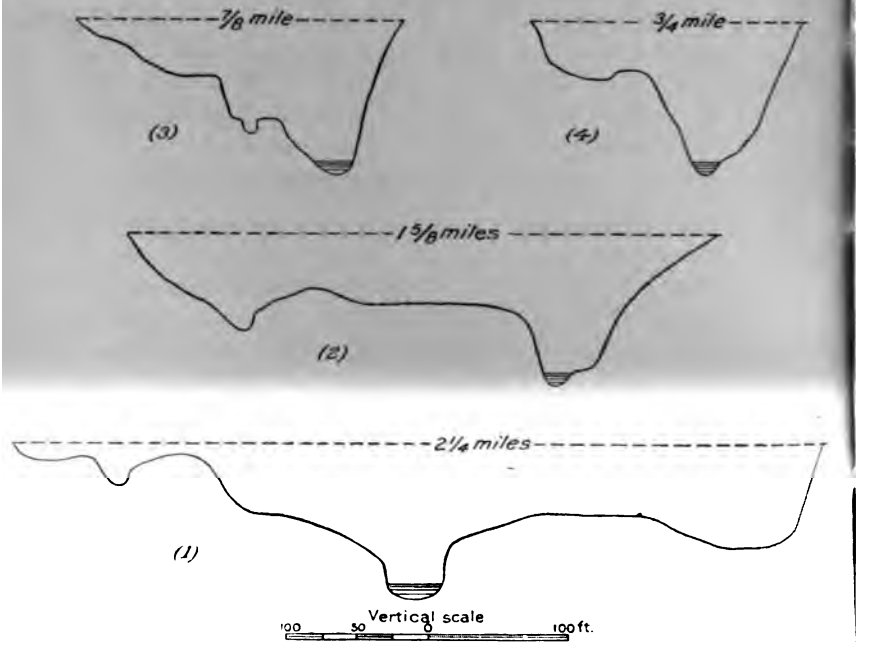


FIG. 1.—Cross sections of Passaic Valley from Clifton to Newark. 1. At Clifton. 2. At Delawanna, 5½ miles below Clifton. 3. At North Newark, 10¼ miles below Clifton. 4. At Newark, 11¼ miles below Clifton.

A striking feature of the lower course of the river, which especially affects it in times of flood, is found in its physiographic relations. From Paterson to Passaic the stream flows in a wide open "old valley;" but from Passaic to its mouth, contrary to usual conditions, its valley assumes more and more the aspect of younger topography, until when near its mouth, just above Newark, it follows a narrow canyon-shaped opening whose sides, especially on the eastern bank, are precipitous. Attention in this connection is called to the several profiles in fig. 1, made at different points from Clifton and Newark, and to the accompanying table of widths at the 100-foot contour from which the cramping of the valley is readily appreciated.

Physiographic phenomena in the neighborhood of Passaic and Rutherford, together with the striking aspect of the lower valley,

seem to indicate that in pre-Glacial times the stream discharged its waters through the gap in the low sandstone ridge at Rutherford now occupied by the Erie Railroad, and that the lower valley, from Newark to Passaic, drained northward through a small tributary which joined the main stream at Rutherford, but owing to the obstruction of the river by extensive glacial filling across its bed in the notch at Rutherford, it was forced to seek a new outlet through the valley of a tributary meeting it from the south.

Whether this be the explanation of the narrowness of the lower valley or not, the restricted limits of this section have an important bearing upon the action of the stream in times of flood, producing a congestion of the waters in excessive freshets which has been of great pecuniary damage to the city of Passaic and the surrounding districts. The building of docks at Newark and the erection of solid masonry piers for bridges, together with a number of elevated causeways for turnpikes crossing the stream and flat lands adjacent, have still further narrowed the already too limited outlet below Passaic.

Like the central basin, the floor of the lower valley is composed of soft Triassic sandstones, more or less overlain by glacial drift.

TRIBUTARIES OF PASSAIC RIVER.

SADDLE RIVER.

In ascending the Passaic from its mouth, Saddle River is the first and only tributary of size in the lower valley. This stream rises in New York, 3 miles north of the State line, flows almost due south for 17 miles, and reaches the Passaic at Garfield. Its course is wholly in the red-sandstone area, which is thickly covered with glacial drift. It has an average fall of 34.1 feet per mile. Its catchment area amounts to 60.7 square miles. The country which it drains is a fertile farming land, with a population of 122 to the square mile, and 28 per cent of its area is still forest. Floods on this stream rise rapidly, remain high but a few hours, and decline as quickly as they arise; the most severe floods occupy from one to two days.

RAMAPO RIVER.

The Ramapo rises in Orange County, N. Y., upon the crystalline highlands and Paleozoic areas; it cuts the trend of the crystalline ridges in a deep gorge, falling 280 feet in 16 miles, from Turners to Suffern, above which point it drains 112.4 square miles. Entering New Jersey at Suffern, it reaches the sandstone area and flows 12 miles to Pompton along the contact of the sandstone and the crystalline rocks, with a fall of 5.7 feet to the mile. Its tributaries in this stage are few, and are mostly from the precipitous slopes of the highlands on its right bank, so that the river as a whole may be regarded as a highland stream. At Pompton, 10 miles below Suffern, the river passes over a natural fall, increased by a dam to 23 feet in height (Pl. VI, *A*); above this dam there is a pond 202 acres in extent.

After passing the dam at Pompton the Ramapo enters the central basin and joins the Pequanac and Wanaque to form the Pompton River. The stream is well adapted to the development of power, and several hundred horsepower upon it are already improved; 75 per cent of the area is in forest, and the population is 58 to the square mile.

WANAQUE RIVER.

Joining the watershed of the Ramapo on the south and west lies the drainage basin of the Wanaque; the topography of its watershed is almost identical with that of the former stream, and its waters are gathered entirely from the Highland area; its source is Greenwood Lake, a lake of glacial origin, which lies between heavily wooded mountains and was formed by the accumulation of drift across a narrow valley. It is 6 miles long with a uniform breadth of five-eighths of a mile. It has a surface area of 1,920 acres and an altitude of 621 feet above sea level. At its outlet is a stone dam 181 feet long and 14 feet high. From Greenwood Lake the river has a length of 18 miles with a general southerly course, mostly through longitudinal valleys of the crystalline Highlands, until it emerges at Pompton and enters the Central Basin, where it joins the Pequanac and Ramapo to form the Pompton. From Greenwood Lake to its junction with the Pequanac it falls 451 feet, or about 26 feet to the mile; 80 per cent of the area of its watershed is in forest, and its population is but 30 to the square mile.

PEQUANAC RIVER.

The watershed of the Pequanac also lies entirely in the Highlands and adjoins that of the Wanaque on the south; in the topography of its watershed and in its general characteristics it closely resembles the area drained by the Wanaque and Ramapo. The Pequanac has a length of 31 miles and rises on the western portion of the Highland belt, which it crosses to the east in a narrow gorge; it has an average drop of 35.1 feet to the mile, falling about 1,100 feet from source to mouth. From a point 2 miles above its mouth to Newfoundland, a distance of 12½ miles, the fall is 45 feet to the mile.

The Pequanac River has been extensively utilized as a source of public water supply; it has natural storage in several ponds of moderate size upon its drainage area, and in the following three large reservoirs built by the East Jersey Water Companies; Oak Ridge reservoir, 16 miles from its mouth, with an area of 383 acres; Clinton reservoir, 13 miles from its mouth, with an area of 423 acres, and Canistear reservoir, about 23 miles above its mouth, with an area of 350 acres. The water collected in these reservoirs is conducted in the open stream to the Makopin intake, a small reservoir 9.5 miles above the mouth, having an area of 12 acres; from this point it is conducted to the city of Newark in a steel conduit. Seventy-five per cent of the area of its watershed is in forest.

A. DAM AT LITTLE FALLS.

B. PASSAIC FALLS AT PATERSON.

ROCKAWAY RIVER.

A third tributary on the Highland area, whose drainage area lies lmost wholly in the Highlands, is the Rockaway; its area adjoins ıat of the Pequanac on the south; it is 40 miles long from source to ıouth and has a fall of 780 feet or 19.5 feet per mile. It has exten-ve storage facilities in natural ponds, among them Splitrock Pond, ixons Pond, Denmark Pond, Green Pond, and Opennaki Lake.

Power is developed at Boonton on the edge of the Highlands 9 miles bove its mouth, and is second only to those at Paterson and Little alls. Like the Pequanac its course is across the Highland ridges, ut its fall is less uniform than that of the last-named stream. Above oonton the stream drains 118 square miles, the population of which 113 to the square mile; 82 per cent of the area is in forest. As the ream leaves the Highlands at Boonton it has a rapid fall to Old oonton, 240 feet in 1.5 miles; at Old Boonton it enters the central asin, and for 2 miles has a fall of 32 feet per mile; 6 miles below it ins the Passaic, with a fall of 2.3 feet per mile. The area of the ntire watershed is 138.4 miles.

WHIPPANY RIVER.

This is a small stream which heads in the Highlands, with most of s course in the morainic hills north of Morristown. It is about 17 iles long, and from its highest source has a fall of 640 feet; it has a rainage area of 71.1 square miles, with a population of 124 to the uare mile; 36 per cent of its area is in forest; 25.4 square miles of s area lie in the Highland area and 45.7 square miles in the central asin. The Whippany is known as a quick-spilling stream.

UPPER PASSAIC RIVER.

The Upper Passaic heads in the Highland area and descends into ıe upper portion of the central basin as a very small stream; in this art of the basin flat lands are found subject to overflow, covering an rea of nearly 10,400 acres; they are confined on the north by the rminal moraine, on the west by the Highlands, and on the south and ast by Long Hill or Third Watchung Mountain, the western member f the concentric series of trap ridges. The Passaic drains this basin ı a narrow gorge cutting the Third Mountain at Millington, from hich point it descends to Chatham, a distance of 17 miles, where it rosses the terminal moraine and enters the central basin proper.

Under present conditions the characteristic functions of the three ıain divisions above described may be stated as follows: The High-ınd area is the chief gathering ground; the central basin, the reser-oir area; the lower valley, the discharge artery. These functions re greatly intensified in times of flood.

SUMMARY.

For the better understanding of the more important relations of the Passaic system the profile of the river and its tributaries is inserted. Attention is particularly called to the important features which control flood conditions as they are illustrated in this diagram. The first of these is the rapid gradient of the tributaries which enter the central basin from the Highland area. The diagram, especially in the cases of the Pequanac and Rockaway rivers, admirably shows the rapid fall from the mountains to the flat valley in the last few miles of their course. The same is true to a lesser extent of the Wanaque, Whippany, and Ramapo rivers. The effect of these comparatively steep grades is emphasized in times of flood by the still steeper valley sides and the high pitch of the small lateral runs and by the abundance of the exposed rock surface of the region. When to these conditions are added a covering of snow or ice and a frozen soil, as was the case at the time of the flood under discussion, the whole region becomes exceedingly "quick spilling" in spite of its large percentage of forests, and pours its waters into the central basin with great rapidity.

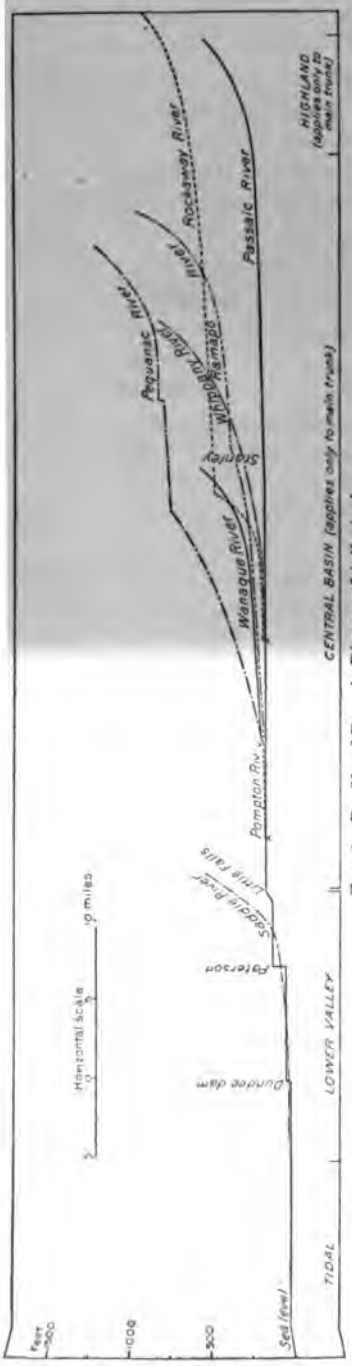


FIG. 2.—Profile of Passaic River and tributaries.

The second important condition indicated by the profile is the exceedingly flat nature of the central basin. From Two Bridges, the mouth of the Pompton River, to Lower Chatham Bridge, 21.5 miles above by stream, the total fall is only 7 feet, and from Little Falls to Stanley, the limits of the flat part of the central basin, a distance of 27 miles, the total fall is only 19 feet. In this portion of the watershed occur the great swamp areas which overflow and remain submerged under flood discharges.

The third important feature is found in the fact that the tributaries which

furnish the largest percentage of water to the main stream enter it in the central-basin area and above the gorge at Little Falls, which, as has been described, is but a narrow outlet.

The fourth interesting and suggestive feature is that from the outlet of the central basin the main trunk of the river reaches sea level by three quick descents at Little Falls, Paterson, and Dundee, between which lie stretches having very little fall. The effect of these level reaches in each case is to retard and accumulate waters which are poured into them, thus helping to produce local overflows which during floods are often disastrous.

As a summary of the important features of the drainage area the following table is added, which shows the total drainage area of the whole system in square miles as well as that of the individual tributaries; also their lengths, proportion of forested areas, fall in feet, and other features.

Table showing drainage areas, forest areas, fall in feet, and gradient of the Passaic and its tributaries.

	Drainage area.	Length of river.	Forests upon watershed.	Drainage area on crystalline highlands.	Drainage area in upper basin.	Drainage area in lower valley.	Fall.	Average gradient.
	Square miles.	*Miles.*	*Per cent.*	*Square miles.*	*Square miles.*	*Square miles.*	*Feet.*	*Feet per mile.*
Passaic proper	299.0	83.5	44	10.0	[a]129.9	115.5	580	6.9
Saddle River	60.7	17.0	28	0.0	0.0	60.7	540	31.8
Pompton River	24.8	6.0	69	0.0	24.8	0.0	10	1.66
Ramapo River	160.7	34.0	72	136.0	24.7	0.0	650	18.8
Wanaque River	109.6	16.5	83	109.6	0.0	0.0	550	33.9
Pequanac River	84.8	31.0	78	83.8	1.0	0.0	1,090	35.1
Rockaway River	138.4	40.0	80	118.2	20.2	0.0	1,030	25.7
Whippany River	71.1	20.0	36	25.4	45.7	0.0	680	34.0
Total	949.1			483.0	289.9	176.2		

[a] 43.6 square miles above Chatham.

FLOW OF PASSAIC RIVER.

Various short-term measurements of the flow of the Passaic River have been made by engineers, and the records appear scattered through reports which have not received wide distribution. Much information regarding the stream was collected and compiled by Mr. C. C. Vermeule, and included in his admirable report to the geological survey of the State of New Jersey.[a] In this report is a series of flow curves covering the years 1877 to 1893.[b] The values represented by these curves were computed from gage-height records, maintained during

[a] Water Supply: Geol. Survey New Jersey, Vol. III, 1894. [b] Ibid., p. 154.

the period mentioned above, along the river between Little Falls and Dundee dam. A tabulation of these values appears in Water-Supply and Irrigation Paper No. 72, and for convenience is reproduced below:

Daily flow of Passaic River at Paterson and Dundee.

[Inches on watershed.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
1877	0.029	0.081	0.202	0.107	0.032	0.021	0.015	0.015	0.013	0.088	0.164	0.081	0.071
1878	.084	.138	.126	.046	.055	.054	.027	.053	.018	.019	.038	.237	.059
1879	.027	.071	.182	.143	.065	.034	.035	.051	.031	.010	.012	.075	.061
1880	.115	.092	.080	.030	.036	.012	.013	.....	.012	.011	.027	.021	.041
1881	.037	.131	.215	.042	.029	.056	.037	.010	.010	.010	.018	.052	.054
1882	.069	.171	.127	.117	.105	.061	.061	.018	.197	.043	.019	.038	.084
1883	.031	.115	.106	.098	.053	.024	.033	.013	.013	.047	.044	.024	.059
1884	.092	.215	.157	.094	.067	.022	.043	.030	.010	.019	.035	.011	.066
1885	.137	.081	.066	.115	.054	.016	.015	.026	.010	.027	.089	.102	.062
1886	.109	.189	.097	.114	.113	.034	.017	.018	.010	.018	.032	.037	.066
1887	.105	.171	.118	.087	.039	.069	.080	.052	.014	.037	.021	.109	.074
1888	.145	.138	.166	.195	.024	.014	.013	.034	.160	.015	.105	.138	.096
1889	.192	.087	.104	.137	.104	.059	.088	.145	.142	.055	.215	.148	.123
1890	.066	.118	.107	.099	.087	.051	.031	.035	.151	.084	.047	.051	.077
1891	.192	.205	.169	.076	.029	.015	.014	.023	.023	.012	.026	.065	.071
1892	.158	.052	.065	.054	.045	.038	.019	.019	.014	.011	.048	.039	.046
1893	.121	.203	.227	.130	.155	.077	.025	.023	.020	.041	.....	.056	.098
Monthly average	.101	.133	.136	.099	.064	.039	.033	.035	.050	.032	.067	.070	.....

Discharge measurements of Pompton River at Two Bridges, N. J.

Date.	Gage height.	Discharge.
1901.	*Feet.*	*Second-feet.*
May 4	3.35	1,837
May 24	2.20	952
June 15	1.60	543
July 11	1.35	304
August 15	1.78	350
August 26	8.32	5,425
October 26	1.30	283
November 22	1.00	195

A. LITTLE FALLS GORGE AT LOW WATER.

B. LITTLE FALLS GORGE AT HIGH WATER.

Discharge measurements of Passaic River at Two Bridges, N. J.

Date.	Gage height.	Discharge.
1901.	*Feet.*	*Second-feet.*
ıy 4	3.88	1,345
ıy 4	4.20	1,198
ıy 24	3.05	626
ne 15	2.50	522
ly 11	2.20	337
ıgust 15	2.75	589
ıgust 26	9.35	3,882
:tober 26	2.20	230
ɔvember 23	1.92	181

Estimated monthly discharge of Passaic River at Two Bridges, N. J

[Drainage area, 300 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1901.					
[ay [a]	2,000	623	1,105	3.07	3.54
une 1–22			779	2.16	1.76
ıly	1,007	137	448	1.24	1.43
ugust	3,858	363	1,409	3.91	4.51
ptember	1,650	271	632	1.76	1.96
:tober	959	225	472	1.31	1.51
ɔvember	719	181	321	.89	.99
ɔcember	4,445	225	1,015	2.82	3.26

[a] Approximate.

Estimated monthly discharge of Pompton River at Two Bridges, N. J.

[Drainage area, 300 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1901.					
May [a]	2,751	893	1,529	4.25	4.90
June 1–22	.....	.....	1,015	2.82	2.30
July	1,254	195	541	1.50	1.73
August	5,342	255	1,834	5.09	5.86
September	2,240	221	848	2.35	2.62
October	1,181	221	533	1.48	1.71
November	1,001	195	322	.89	.99
December	6,328	300	1,441	4.00	4.61

[a] Approximate.

Daily gage height, in feet, of Pompton River at Two Bridges, N. J., for 1901.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.90	1.20	1.70	4.00	2.30	1.10	1.30
2	3.10	3.75	1.85	1.45	3.80	2.00	1.10	1.30
3	3.50	3.70	2.05	1.55	3.50	2.00	1.10	1.35
4	3.35	3.40	2.25	1.35	2.95	2.00	1.10	1.75
5	2.95	3.05	2.45	1.20	2.60	1.75	1.10	1.90
6	2.65	2.80	2.60	1.20	2.45	1.65	1.10	1.66
7	2.45	2.60	2.65	3.25	2.20	1.50	1.10	1.75
8	2.15	3.51	2.65	3.90	2.00	1.40	1.10	1.70
9	2.20	3.50	1.85	3.15	2.85	1.30	1.10	1.60
10	2.85	2.80	1.50	2.65	1.65	1.30	1.10	1.16
11	4.50	2.45	1.30	2.45	2.65	1.30	1.10	2.25
12	4.70	2.15	1.45	2.25	2.65	1.30	1.15	2.05
13	4.30	1.95	1.60	2.05	1.70	1.25	1.25	1.90
14	3.60	1.60	1.60	2.00	1.50	1.95	1.45	2.45
15	3.55	1.50	1.40	1.85	1.50	2.55	1.20	3.40
16	3.20	1.50	1.15	1.55	1.85	2.45	1.20	3.90
17	2.85	1.45	1.35	1.50	2.05	2.30	1.20	4.90
18	2.60	1.45	2.65	3.20	2.00	2.15	1.20	4.20
19	2.65	1.25	1.65	4.55	2.00	2.00	1.10	3.90
20	2.45	1.20	1.60	4.25	1.85	1.75	1.10	3.65
21	2.50	1.15	1.20	3.60	1.45	1.60	1.00	3.30
22	2.15	1.00	1.00	5.15	1.40	1.50	1.00	3.10
23	2.30	1.00	1.00	5.00	1.40	1.40	1.00	2.60
24	2.15	1.15	1.00	6.50	1.40	1.30	1.10	1.95
25	2.40	1.10	1.00	8.25	1.30	1.30	1.65	1.80
26	2.75	1.15	1.00	7.15	1.20	1.30	2.30	1.55
27	2.80	.90	1.00	6.10	1.10	1.25	1.95	2.35
28	3.50	.90	1.00	5.15	1.10	1.20	1.90	2.70
29	3.50	.90	1.30	4.55	1.50	1.20	1.70	2.80
30	4.00	.90	1.75	4.05	2.50	1.10	1.55	7.10
31	4.30	.....	1.75	3.85	.....	1.10	.....	9.60

ge height, in feet, of Passaic River at Two Bridges, N. J., for 1901.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	.....	4.75	1.80	2.75	4.95	3.15	2.00	2.00
	3.90	4.55	2.10	2.50	4.80	3.00	2.00	2.00
	4.25	4.55	2.30	2.50	4.40	3.00	2.00	2.05
	4.20	4.30	2.70	2.50	4.10	3.00	2.00	2.60
	4.05	3.95	3.10	2.80	3.75	2.85	2.00	2.95
	3.60	3.65	3.60	2.30	3.50	2.65	2.00	2.85
	3.30	3.45	3.65	4.20	3.20	2.45	2.00	2.70
	3.05	4.35	3.45	4.80	3.00	2.40	2.00	2.65
	2.95	4.05	2.70	4.00	2.90	2.30	2.00	2.50
	3.05	3.85	2.25	3.70	2.60	2.25	2.00	2.40
	5.05	3.40	2.20	3.45	2.50	2.20	2.00	2.95
	5.60	3.15	2.45	3.25	2.60	2.20	2.05	2.85
	5.15	2.95	2.55	3.05	2.60	2.20	2.20	2.80
	4.85	3.00	2.50	3.00	2.55	2.85	2.30	2.85
	4.45	2.50	2.30	2.75	2.45	3.55	2.10	3.20
	4.05	2.40	2.25	2.50	2.65	3.45	2.10	6.80
	3.90	2.30	2.40	2.50	2.85	3.20	2.10	5.90
	3.40	2.15	3.55	4.10	2.80	2.95	2.10	5.15
	3.50	1.95	2.60	5.55	2.65	2.80	2.00	4.85
	2.95	1.95	2.50	5.20	2.50	2.60	2.00	4.20
	3.15	1.90	2.15	4.50	2.45	2.50	2.00	3.00
	3.00	1.85	2.00	6.15	2.40	2.50	2.00	3.00
	3.00	1.90	2.00	6.00	2.20	2.20	1.90	2.95
	3.05	2.00	2.00	7.05	2.20	2.20	2.35	2.70
	3.25	2.05	2.00	9.30	2.20	2.20	2.65	2.55
	3.60	1.90	2.00	8.50	2.10	2.10	3.05	2.40
	3.95	1.90	2.00	7.35	2.10	2.05	3.00	3.20
	4.40	1.80	2.00	6.35	2.10	2.00	3.00	3.80
	4.40	1.80	2.20	5.45	2.40	2.00	2.65	3.70
	4.65	1.80	2.70	5.00	3.35	2.00	2.30	8.70
	4.90	.....	2.75	5.10	.....	2.00	.....	10.45

Daily gage height, in feet, of Pompton River at Two Bridges, N. J., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.35	3.00	10.40	4.35	3.30	2.15	2.50	2.75	1.30	4.55	2.75	1.30
2	7.55	3.50	14.40	4.15	3.05	1.75	2.25	2.65	1.20	4.35	2.70	1.6
3	6.45	3.70	14.00	3.40	2.80	1.30	2.00	2.55	1.10	4.70	2.70	1.70
4	6.25	3.50	10.80	3.25	2.95	1.30	2.10	2.30	1.10	4.45	2.65	2.00
5	5.15	3.40	9.75	3.15	2.55	1.20	2.00	2.10	1.10	4.45	2.55	2.00
6	4.00	3.30	8.40	3.00	2.40	1.20	1.85	2.00	1.10	4.75	2.35	2.10
7	3.30	2.60	7.15	3.15	2.15	1.10	1.65	1.85	1.00	4.50	2.25	2.10
8	2.95	2.10	6.15	3.65	2.00	1.10	1.45	1.70	1.10	4.25	2.20	2.20
9	2.55	1.90	6.55	5.30	2.00	1.10	1.40	1.60	1.10	3.95	2.05	2.35
10	2.35	1.70	7.35	6.60	1.85	1.00	1.40	1.50	1.20	3.60	1.90	2.25
11	2.25	1.50	7.70	6.60	1.50	1.00	1.35	2.55	1.25	3.30	1.80	2.10
12	2.35	1.50	7.45	6.15	1.30	1.00	1.30	2.95	1.30	4.60	1.55	2.10
13	2.30	1.40	7.30	5.80	1.30	1.05	1.20	3.60	1.40	5.05	1.45	2.00
14	2.20	1.40	7.50	4.55	1.30	1.25	1.20	3.50	1.50	4.85	1.35	1.90
15	2.05	1.30	7.15	4.05	1.20	1.30	1.20	3.50	1.50	4.65	1.30	1.85
16	1.50	1.20	7.00	3.60	1.20	1.30	1.20	2.25	1.40	4.35	1.30	2.30
17	1.60	1.20	5.90	3.40	1.20	1.30	1.10	3.05	1.15	3.65	1.30	5.65
18	1.50	1.20	6.60	3.10	1.15	1.30	1.20	2.70	1.10	3.40	1.20	8.25
19	1.45	1.10	5.55	2.60	1.10	1.25	1.30	2.55	1.10	3.00	1.20	8.20
20	1.30	1.20	4.65	2.50	1.20	1.25	1.30	2.65	1.10	2.95	1.20	8.00
21	1.30	1.30	4.35	2.50	1.20	1.35	1.35	2.45	1.10	2.80	1.20	8.00
22	5.75	1.50	4.10	2.40	1.20	1.70	1.50	2.25	1.10	2.65	1.10	7.55
23	7.75	1.70	3.75	2.40	1.10	1.65	1.45	2.15	1.00	2.40	1.00	7.90
24	6.85	1.85	3.40	2.30	1.10	1.50	1.40	1.90	1.10	2.05	1.00	9.55
25	5.45	2.45	3.15	2.20	1.20	1.50	1.75	1.60	1.25	1.85	1.20	9.25
26	4.35	4.30	2.85	1.90	1.75	1.50	2.15	1.45	2.70	1.75	1.30	8.30
27	4.30	7.20	2.60	1.65	2.15	1.65	2.20	1.20	3.30	1.65	1.45	8.05
28	4.05	8.60	2.45	1.60	2.75	1.55	2.20	1.35	3.95	2.40	1.50	7.20
29	3.45	.....	3.30	2.40	2.80	1.35	2.15	1.40	4.60	2.85	1.40	6.65
30	3.15	.....	4.55	3.00	2.45	2.45	2.70	1.30	4.55	3.00	1.30	6.65
31	3.20	.....	4.45	.....	2.25	.....	2.85	1.30	.....	3.90	.....	6.55

A. FALLS, POMPTON LAKE.

TTLE *FALLS GORGE*, LOOKING UNDER MORRIS CANAL VIADUCT, HIGH WATER.

gage height, in feet, of Passaic River at Two Bridges, N. J., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
.....	9.25	3.70	11.55	5.25	4.40	3.10	3.30	3.75	2.30	5.55	3.75	2.20
.....	8.25	4.35	13.50	5.15	4.10	2.70	3.25	3.65	2.20	5.95	3.70	2.45
.....	7.45	4.50	12.80	4.65	3.80	2.40	3.00	3.55	2.15	5.70	3.65	2.70
.....	7.40	4.30	11.80	4.40	3.95	2.30	3.10	3.30	2.00	5.55	3.55	3.00
.....	7.05	4.15	10.75	4.15	3.55	2.20	3.00	3.10	2.00	5.45	3.35	3.00
.....	6.90	4.00	9.40	4.00	3.40	2.15	2.85	3.00	2.00	5.75	3.30	3.10
.....	4.50	3.80	8.15	4.15	3.15	2.10	2.65	2.85	2.00	5.50	3.20	3.10
.....	3.90	3.60	7.20	4.60	3.00	2.10	2.55	2.70	2.10	5.25	3.20	3.20
.....	3.50	3.40	7.50	6.25	3.00	2.10	2.40	2.60	2.10	4.95	3.05	3.35
.....	3.20	3.20	8.35	7.65	2.85	2.00	2.40	2.45	2.20	4.60	2.90	3.25
.....	3.00	3.20	8.70	7.65	2.50	2.00	2.35	3.50	2.25	4.30	2.80	3.10
.....	3.40	2.90	8.45	7.15	2.30	2.00	2.30	3.95	2.30	5.55	2.55	3.10
.....	3.25	2.60	8.30	6.70	2.30	2.20	2.20	4.60	2.40	6.05	2.45	3.00
.....	3.10	2.30	8.50	5.55	2.30	2.30	2.20	4.50	2.50	5.85	2.35	2.90
.....	2.80	2.10	8.15	5.10	2.30	2.30	2.20	4.50	2.50	5.65	2.30	2.85
.....	2.50	2.10	8.00	4.60	2.20	2.20	2.20	4.25	2.40	5.15	2.30	2.80
.....	2.50	2.10	6.90	4.40	2.20	2.30	2.10	4.05	2.15	5.65	2.30	6.65
.....	2.50	2.10	7.55	4.10	2.15	2.30	2.20	3.70	2.10	4.40	2.20	9.25
.....	2.45	2.20	6.75	3.40	2.10	2.25	2.25	3.55	2.10	4.00	2.20	9.20
.....	2.40	2.30	5.65	3.50	2.20	2.25	2.30	3.60	2.10	3.95	2.20	9.00
.....	2.00	2.45	5.35	3.50	2.20	2.40	2.35	3.35	2.10	3.80	2.20	9.00
.....	5.65	2.65	5.10	3.40	2.20	2.80	2.50	3.20	2.10	3.65	2.10	8.55
.....	8.80	2.70	4.75	3.40	2.10	2.75	2.45	3.05	2.00	3.40	2.00	8.95
.....	7.95	3.40	4.40	3.30	2.10	2.60	2.40	2.90	2.10	3.05	2.00	10.55
.....	6.80	3.90	4.15	3.20	2.25	2.60	2.75	2.60	2.25	2.85	2.20	10.25
.....	5.80	5.45	3.75	2.80	2.60	2.50	3.15	2.35	2.85	2.75	2.30	9.45
.....	5.70	8.15	3.50	2.65	2.95	2.65	3.20	2.20	3.60	2.65	2.45	9.05
.....	5.45	9.60	3.35	2.65	3.35	2.55	3.20	2.35	4.55	3.40	2.50	8.20
.....	4.75	.....	4.25	3.30	3.65	2.40	3.15	2.40	5.60	3.60	2.40	7.65
.....	4.40	.....	5.55	3.90	3.45	3.30	3.70	2.30	5.55	4.00	2.30	7.65
.....	3.80	.....	5.35	.....	3.25	.....	3.85	2.30	.....	3.90	.....	7.55

Estimated monthly discharge of Passaic River at Two Bridges, N. J.

[Drainage area, 360 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1902.					
January	3,832	225	1,616	4.49	5.18
February	4,011	271	1,003	2.79	2.91
March	[a] 11,600	863	2,863	[a] 7.95	[a] 9.16
April	3,016	527	1,424	3.96	4.42
May	1,375	271	618	1.72	1.98
June	839	225	408	1.13	1.26
July	1,103	271	550	1.53	1.76
August	1,475	317	808	2.24	2.58
September	1,975	225	488	1.36	1.52
October	2,200	527	1,467	4.08	4.70
November	1,055	225	534	1.48	1.65
December	4,496	317	2,071	5.75	6.62
The year	[a] 11,600	225	1,154	3.21	43.75

[a] Estimated.

Estimated monthly discharge of Pompton River at Two Bridges, N. J.

[Drainage area, 360 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1902.					
January	5,415	300	2,080	5.78	6.66
February	5,598	221	1,180	3.28	3.42
March	[a] 11,600	1,109	[a] 4,050	[a] 11.25	[a] 12.97
April	4,138	505	1,867	5.19	5.79
May	1,729	221	703	1.95	2.25
June	1,109	195	376	1.04	1.16
July	1,400	221	583	1.62	1.87
August	1,948	255	969	2.69	3.10
September	2,678	195	569	1.58	1.76
October	3,006	540	1,927	5.35	6.17
November	1,327	195	575	1.60	1.79
December	6,291	255	2,795	7.76	8.95
The year	[a] 11,600	195	1,473	4.09	55.89

[a] Estimated.

Miscellaneous measurements in Passaic watershed.

Date.	Stream.	Locality.	Discharge.
1902.			*Sec.-feet.*
June 26	Ramapo River	Mahwah, N. J.	123
Oct. 29	do	do	678
Sept. 24	Rockaway River	Old Boonton, N. J	33
Aug. 23	do	do	146
Sept. 11	do	do	164
Sept. 23	do	do	102
Oct. 30	do	do	488
Oct. 30	Pompton River	Pompton Plains, N. J	1,066
Sept. 26	Passaic River	Stanley, N. J	195
Oct. 30	do	do	431
Sept. 26	do	Millington, N. J	92
Aug. 28	Whippany River	Whippany, N. J.	35.3
Sept. 23	Pequanac River	Pompton, N. J	90
Aug. 22	Wanaque River	do	97

During the past year the Division of Hydrography has made current-meter measurements on both the Pompton and Passaic rivers near their junction at Two Bridges, and for low-water stages of the rivers these measurements show with fair accuracy the volume of both streams.

During the progress of floods, however, measurements taken at these stations can not be relied upon to furnish complete data of the discharge, for the reason that the Pompton, a comparatively swift-flowing stream, enters the Passaic, a sluggish stream, at nearly right angles, cutting across its current and acting as a temporary dam in backing up its waters to a greater or less extent. In this way the gage-height readings on the Passaic, which are taken just above the junction, do not in flood time bear their true value to the discharge of the stream.

Another feature which detracts from the accuracy of flood measurements at Two Bridges is the fact that both rivers overflow their banks and spread over a wide section of flat lands during high freshets; so that while the gage readings have a certain interest and value, they do not accurately record the true height of the water which should pass between the banks. Therefore in this discussion neither the discharge measurements nor the gage-height records have been considered.

Attention is particularly called to the fluviographs of the Passaic and Pompton rivers (figs. 3 and 4) made from daily gage heights and frequent current-meter discharge measurements at Two Bridges, at the junction of these streams. They clearly reveal several important features in the flow of the rivers above mentioned. In the considera-

tion of them it should be borne in mind that the drainage areas of both the Passaic and Pompton rivers above the point of measurement are nearly equal in extent, and, furthermore, that they are adjacent. There is, however, this important difference between them with respect to topography and physical conditions, namely, that the catchment

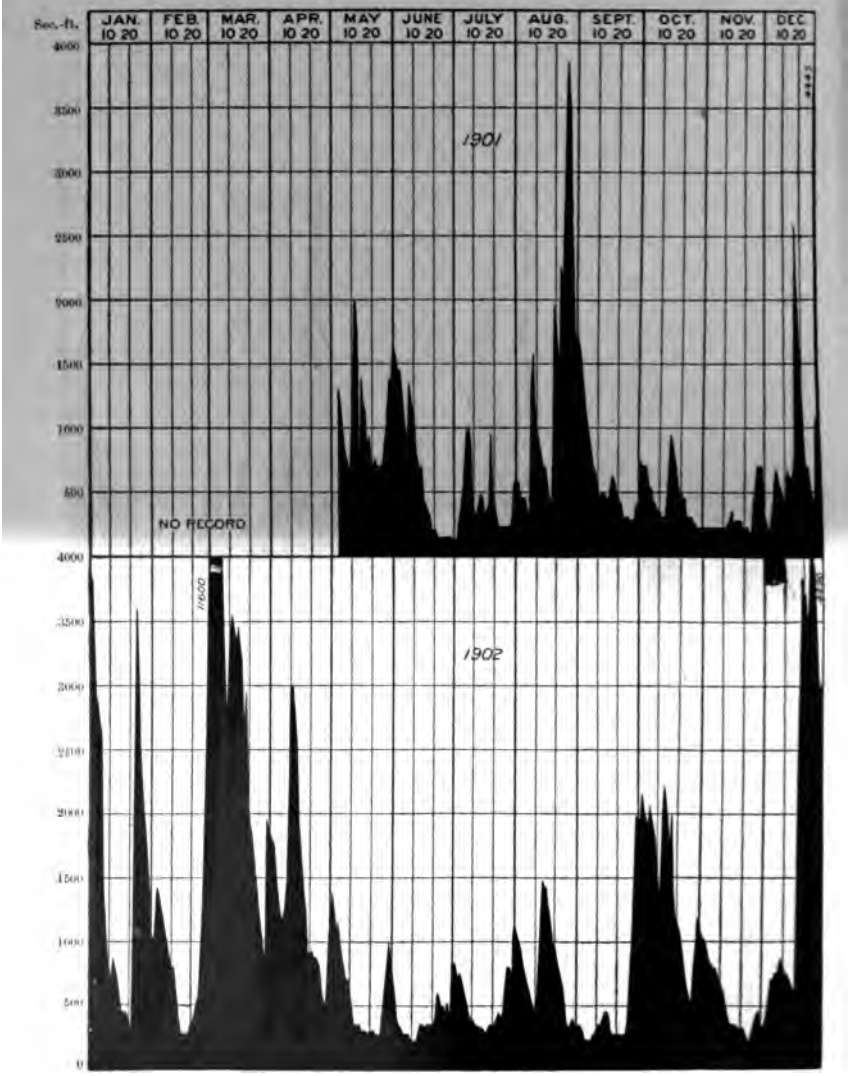


FIG. 3.—Discharge of Passaic River at Two Bridges.

basin of the Pompton lies almost entirely in a mountainous and heavily forested area of the Highlands, while that of the Passaic lies mainly in the comparatively flat cultivated area of the central basin.

The fluviographs show in a striking way the great irregularity in the flow of the streams. The quick and violent rises occur in al

ıths of the year, being naturally more prolonged in the spring than he summer season, and the normal and comparatively small flow he stream is during intervals between these rises.

he rises occur on both streams simultaneously, as is to be expected ı the proximity of the drainage areas, which naturally would

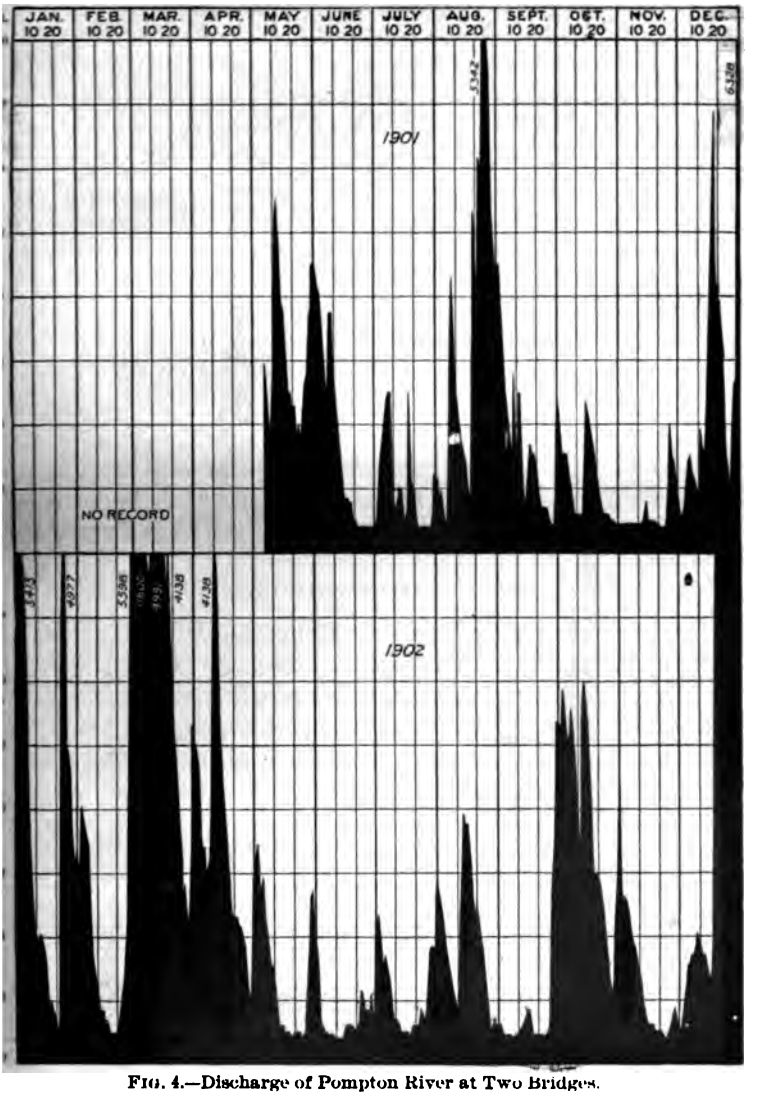


FIG. 4.—Discharge of Pompton River at Two Bridges.

ve about the same amount of precipitation during any given d. The rises on the Pompton River are in each case greater than on the Passaic. This at first is difficult to understand, in view e fact that the drainage area of the Pompton is heavily forested, a large portion of the Passaic Basin, exclusive of the Rockaway,

whose waters in this instance are included, contains a comparatively small proportion of forests. In other words, the Pompton as compared with the Passaic watershed is quick spilling. A moment's inspection of other conditions serves to explain the anomaly of the flow; for not only are the grades on the Pompton watershed much steeper than those on the Passaic, the Rockaway River excepted, but this part of the Passaic Basin contains also the large areas of flat and swamp lands previously referred to, which not only retard the flow of the streams, but, in the case of the swamp areas, act as a great natural reservoir for the waters at all times, absorbing the high waters which readily flood their surface, and contributing a constant supply back to the main stream in times of low-water flow. Owing to this regulating effect of the wet lands in the central basin, it is easy to account for the lower rises of the Passaic, as well as for the greater volume of its low-water flow, as compared with that of the Pompton, so clearly brought out by the fluviographs.

These characteristics of flow are, of course, greatly emphasized at times of extraordinarily high water, as during the flood under discussion. In such times, of course, the action of the waters becomes more complicated owing to the fact that the Pompton discharges its flood crest so rapidly that it acts as a temporary check to the Passaic, the waters of the former cutting across the channel of the latter at Two Bridges and increasing the flooding effect of the Passaic over the lowlands above.

FLOOD OF 1902.

High water is not uncommon in the Passaic Valley. It occurs, as will be seen by reference to previous discharge tables and diagrams, several times a year, but though it comes with reasonable frequency it is not often violent. The large area of swamp and wet lands in the central basin is regularly flooded each spring, as are often farm lands adjoining these tracts. Lower down the valley waters may often rise to low bench lands and give some inconvenience in towns and villages. As far as the sewage pollution of the lower valley is concerned, these high waters are of a decided advantage, serving to flush that portion of the river and temporarily cleansing it from excess of sewage.

When, however, the precipitation on the drainage area becomes great, or when a variety of circumstances combine to deliver a large amount of water—as, for example, an accummulation of snow is rapidly melted on frozen ground by a warm and heavy rain—the flood conditions resulting in the lower parts of the valley are quite different in character. The central basin is widely flooded by a quick discharge of the highland tributaries, resulting in hardship and loss to the farming population of this area. The narrow gorge at Little Falls, whose capacity is made still less by the constricted opening of the old masonry span which supports the Morris Canal aqueduct (see

A. ROCKAWAY RIVER AT BOONTON.

B. DAM AT DUNDEE.

VI, *B*), is unable to discharge its waters fast enough to keep them m flooding the lands above, while in the lower valley the waters ade both the cities of Paterson and Passaic, doing great damage to manufacturing and residential properties and threatening the aller settlements located on the lower portion of the river.

Floods of this nature have periodically occurred in this region and e resulted in widespread suffering and damage. Such a flood took ce from February 25 to March 9, 1902, reaching its height at noon on day, March 2. It was the highest flood within the memory of the est inhabitant of the region, and owing to the fact that population l manufacturing interests have greatly increased in portions of the ley during recent years, it was probably the most destructive. The its of the flood will be taken as the time during which the water el was above full bank. In the previously mentioned report of the w Jersey geological survey on the water resources of the State, the l bank flow at Dundee dam has been determined at 4,000 cubic t per second; our measurements and observations lead us to believe t 5,000 cubic feet is more nearly correct. In any case the differce is not sufficient to effect any significant discrepancy in determin- the duration of the flood.

The discharge measurements hereinafter set forth were made with small Price current meter, according to the methods practiced by e Division of Hydrography, except in the cases of Little Falls and ndee dams. At the latter points gages were read at short intervals d the amount of water was determined by Bazin's series modified conform with the local conditions and requirements.

PRECIPITATION IN THE PASSAIC VALLEY.

The records of numerous weather observation stations in the Passaic ainage area and those of other stations in the country immediately rrounding afford a trustworthy basis of measurement of precipitan over the basin. The following table is a statement of the normal ount of precipitation at the various stations during the month of bruary, 1902. It should be borne in mind that the month of Febary is usually marked by considerable precipitation and that the rmal for that period is, in most places, comparatively high. This sult is a relatively large flow in river channels. Therefore an crease over the normal of 2 inches in the month of February ans more, from the standpoint of damage by river floods, than it uld in a dry season when the river had been in low stages. In er words, the addition of 2 inches of rainfall to the flow of a stream ile it was running fairly high would cause more damage than would addition of a similar amount to the river at a low stage.

Precipitation in inches in the Passaic Valley and adjoining country in February, 1902.

Station.	County.	Normal.	Total for month.	Departure from normal.	Greatest in 24 hours.	Total snowfall unmelted.
HIGHLAND REGION.						
Dover	Morris	4.16	6.93	2.77	2.80	18.0
Chester	do	4.30	5.31	1.01	1.70	18.6
Charlotteburg	do	4.97	6.85	1.88	2.65	13.0
Ringwood	Passaic	.....	6.70	.....	1.90	20.7
RED SANDSTONE PLAIN.						
Paterson	Passaic	4.63	8.15	3.52	3.03	25.5
Hanover	Morris	3.75	8.44	4.69	3.30	20.5
Rivervale	Bergen	4.89	7.53	2.64	1.60	21.0
Roseland	Essex	.....	6.90	.....	1.64	15.2
Newark	do	3.65	5.35	1.70	1.30	15.4
South Orange	do	4.22	5.69	1.47	1.64	18.5
New York City	New York	3.80	5.78	1.98	1.47	13.4
Plainfield	Union	3.96	7.65	3.69	1.72	23.2
Elizabeth	do	4.55	7.83	3.28	1.60	23.0
Average		4.26	6.85	2.60	1.89	18.9

The record of these stations show that during the month of February, 1902, the precipitation was heavy, and that the storms occurred on eight days of the month, namely, the 1st, 2nd, 17th, 21st, 22d, 25th, 26th, and the 28th. There was in various places an insignificant amount of rainfall on other days, but the total is so small in comparison with the precipitation for the month that it may be disregarded without introducing errors. In the following table the amount of rainfall is recorded at the various stations during the eight days mentioned.

ily precipitation in inches in and adjoining the Passaic Valley in February, 1902.

	Day of month.							
	1.	2.	17.	21.	22.	25.	26.	28.
HIGHLAND REGION.								
ver	(a)	0.73	0.90	(a)	2.80	(a)	0.90	1.60
ester	0.20	.65	.96	1.70	.20	0.40	.70	.40
arlotteburg	(a)	.62	.60	(a)	2.00	(a)	.98	2.65
ngwood	.15	.70	.95	.45	1.90	.06	.54	1.81
RED SANDSTONE PLAIN.								
terson	.62	.61	1.10	3.03	.20	1.15	.05	1.39
anover	.27	.77	.90	(a)	3.30	.75	.65	1.60
vervale	(a)	1.58	1.30	(a)	2.30	(a)	1.60	.75
seland	.10	.55	.74	1.64	1.20	.61	.81	1.25
ewark	.12	.40	1.30	(a)	1.28	.55	.60	1.10
uth Orange	(a)	.60	1.00	1.64	.20	.78	.30	1.13
ew York City	.19	.54	.93	1.02	1.47	.19	.98	.42
ainfield	.18	.61	1.72	1.21	1.33	.34	.88	1.35
lizabeth	.36	.53	1.60	(a)	2.70	.60	.64	1.40
Average	.91	.68	1.08	.82	1.61	.45	.74	1.30

a Included in record for following day.

Examination of the two tables above set forth shows clearly, first, at the month of February, 1902, was characterized by heavy pre-pitation, which exceeded the normal, and at many stations to an xtraordinary degree; second, the precipitation occurred on eight ays of the month, and by far the largest part of it on the 17th, 21st, d, 25th, 26th, and 28th. Closer examination will show that the pre-pitation at the stations within the Passaic Basin was heavier than the stations outside of the same, and while the latter undoubtedly rved to steady the general average, they also make an actual reduc-on when computed with the former. Therefore there can be no estion that the adoption of the general average for all the stations a measure of the amount of precipitation in the Passaic Valley is fe and conservative.

Our interest chiefly centers upon the last twelve days of the month; at is, from the 17th to the 28th, inclusive. During that period there as a fall of 6 inches over the whole basin. This average will not rve in any calculation of the relation of run-off to the rainfall dur-g the flood, because of the fact that there were so wide differences the amount of precipitation in places not widely distant from one nother. The average of 6 inches over the whole basin is but an pproximation and does not represent accurately the actual amount

of water precipitated, hence any estimation of the proportion of rainfall to run-off must be precarious and, in all probability, incorrect.

The character of this enormous precipitation as it fell is an important consideration. The heavy snow of the 17th, equivalent to 1.08 inches, had not melted to any extent by the 21st and 22d, when it was reenforced by a destructive sleet equivalent to 2.43 inches over the drainage area, and at some stations to over 3 inches. There was a general rise of temperature on the 23d and 24th, during which a small amount of snow was melted, and about the same temperature was maintained during the 25th and 26th, on which days the total precipitation was 1.19 inches. On the 28th there was a short but tremendous downfall, amounting to 1.22 inches, and at the end of this storm the snow of the 17th had practically all disappeared. This means that from the 23d to the 28th, or during six days, nearly 6 inches of water were heaped upon the Passaic Basin, the greater proportion of which fell or was released through the melting of snow during the last four days.

GAGE HEIGHTS.

A precipitation so great and so rapidly delivered over an area the surface of which was frozen could not fail to produce extraordinary results. We find that on the Upper Passaic River, at Chatham, the water began to rise on Thursday, February 27, reaching a maximum on the afternoon of Saturday, March 1. On the Whippany River, at Whippany Village near the mouth, the water began to rise on Friday about noon and reached a maximum at 10 o'clock p. m. on the same day, falling almost immediately. On the Rockaway River at Boonton (see Pl. VII, A) occurred the highest water since February 6, 1896, when the recorded height was 6 feet above the crest of the Boonton dam. On the present occasion the rise of water began on the afternoon of Friday, February 28, and reached its highest point March 1 at 3 a. m., at 5.55 feet above the crest. For seven hours, beginning on February 28 at 8 p. m., the rise was 2 inches per hour. The appreciable decline in flood flow began Monday, March 3, and by March 4 the water had lowered to 1 foot over the dam crest.

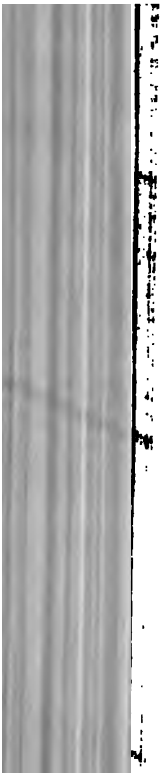
At the feeder of the Morris Canal at Pompton Plains, below the junction of Pequanac, Wanaque, and Ramapo rivers, the following gage readings were reported by Mr. L. M. Le Fevre:

Height of water at feeder of Morris Canal.

	Feet.
February 28, 4 p. m	4.4
March 1, 6.10 a. m	7.4
March 2, 5.10 p. m	5.4
March 3, 2.30 p. m	5.5
March 4, 2.20 p. m	4.2
March 5, 7.40 a. m	3.9
March 6, 4.10 p. m	3.4
March 7, 6.50 a. m	2.0
March 8, 1.20 p. m	2.0

A. MEASUREMENT STATION AT STANLEY ON PASSAIC RIVER.

B. MEASUREMENT STATION AT WHIPPANY ON WHIPPANY RIVER.



On the Ramapo River at Pompton Furnace the highest water was observed at 6 p. m. on March 1, where it reached 4.1 feet above the dam crest. The combined flow of the Wanaque and Pequanac rivers was measured at the Van Ness farmhouse in Pompton Plains, and indicated a beginning of rise on February 28 in the early afternoon, reaching a maximum on March 1 shortly before noon. The high water was maintained fairly steady during March 1 and 2 and by March 5 had retreated within its banks.

The great volume of water poured out upon the central basin raised the level to such a height at Two Bridges, the junction of the Passaic and Pompton rivers, that the gages maintained there by the Division of Hydrography were submerged and the water flowed around the bridges and inundated the neighboring fields.

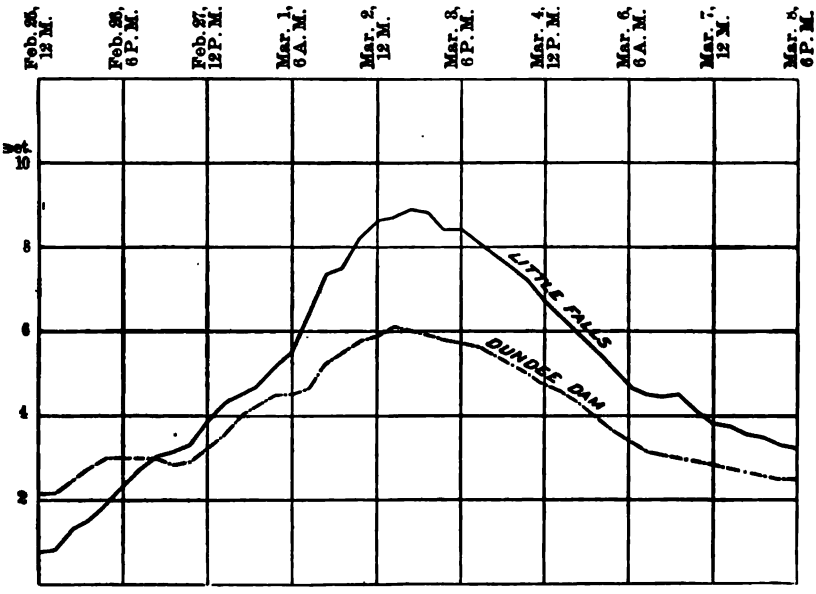


FIG. 5.—Diagram of gage readings at Little Falls and Dundee dam during flood of 1902.

At Little Falls and at Dundee dam, just above Passaic, gage readings have been preserved and are diagrammatically shown in fig. 5.

A brief description of the two dams and the conditions surrounding them will be desirable in connection with the consideration of fig. 5. The Little Falls dam is constructed with two wings adjoining the main dam, which occupies a transverse position across the center of the stream. Fig. 6 shows the plan of the site to good advantage, while the general appearance during flood is faithfully represented in pl. IV, *A*. The main dam is 160 feet in length, with an elevation of 157.18 above tide; the north wing is 64 feet long and has an elevation of 157.81 feet, while the south wing, constructed parallel to the channel, is 61 feet long, the crest being at an elevation 157.56 feet above tide. The dam at Dundee is built of stone, the crest being 27 feet

above mean tide. It is 480 feet in length and has a width of 3 fe
the crest, holding back a pond of 224 acres. (See Pl. VII, *B*.)

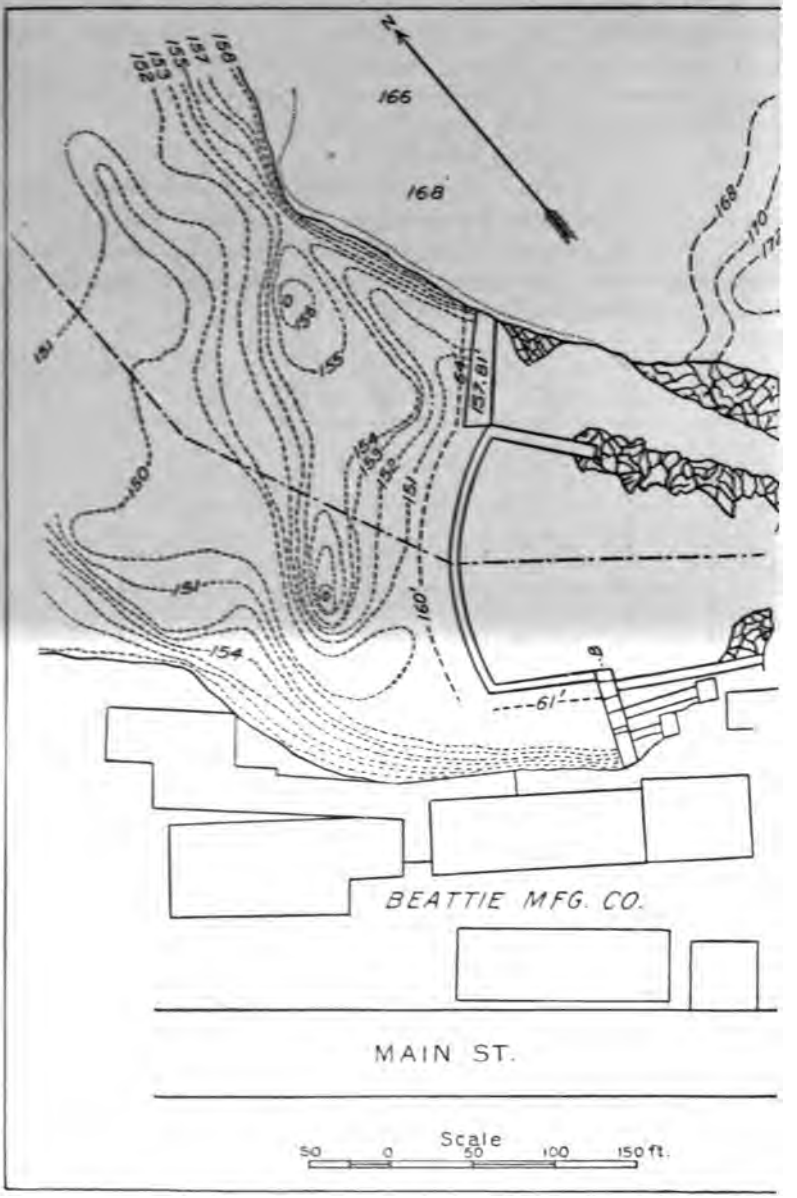


FIG. 6.—Plan of Beattie's dam, Little Falls.

FLOOD FLOW OF HIGHLAND TRIBUTARIES.

From the records of two series of current-meter measure
taken at different gage heights during the two weeks followi
ood, and the marks made by eyewitnesses during the flood p

g tables have been constructed for each of the Highland tribu- s which seem to bear the test of reasonable analysis and to fur- valuable information concerning the discharge of the various ms. This discharge in second-feet for six-hour periods during lood—that is, from February 25 to March 9—is set forth in the below.

ge flow in second-feet of Highland tributaries during six-hour periods, February 25 to March 9, 1902.

ate.	Time of day.	Upper Passaic.[a]	Whippany.	Rockaway.	Pequanac.	Wanaque.	Ramapo.	Total.
ary 26...	12- 6 a. m.....	134	95	185	110	148	216	888
	6-12 a. m.....	218	155	302	185	239	351	1,450
	12- 6 p. m	379	270	520	322	416	573	2,480
	6-12 p. m	523	372	725	444	574	842	3,480
ary 27..	12- 6 a. m.....	500	430	800	500	650	850	3,730
	6-12 a. m.....	590	490	850	650	745	865	4,190
	12- 6 p. m	625	550	900	800	954	880	4,709
	6-12 p. m	650	610	1,000	970	1,145	890	5,265
ary 28...	12- 6 a. m.....	670	650	1,050	1,000	1,237	900	5,507
	6-12 a. m.....	700	712	1,300	1,440	1,745	1,200	7,097
	12- 6 p. m	728	846	1,436	1,690	2,300	1,700	8,670
	6-12 p. m	875	1,071	1,636	2,225	2,600	3,100	11,507
1	12- 6 a. m.....	1,050	1,505	2,535	2,725	3,050	4,400	15,265
	6-12 a. m.....	1,440	1,470	2,780	3,350	3,900	5,000	17,940
	12- 6 p. m	1,630	1,430	2,780	3,900	3,900	5,150	18,790
	6-12 p. m	1,630	1,380	2,780	4,215	3,900	5,225	19,130
2	12- 6 a. m.....	1,600	1,340	2,780	4,280	3,900	5,280	19,180
	6-12 a. m.....	1,550	1,300	2,780	4,350	3,900	5,120	19,000
	12- 6 p. m	1,500	1,260	2,780	4,330	3,525	4,000	17,395
	6-12 p. m	1,440	1,220	2,780	4,050	3,075	3,450	16,015
3	12- 6 a. m.....	1,400	1,180	2,527	3,400	2,875	3,050	14,432
	6-12 a. m.....	1,355	1,140	2,690	3,275	2,750	2,850	14,060
	12- 6 p. m	1,310	1,100	2,645	3,150	2,675	2,780	13,660
	6-12 p. m	1,250	1,060	2,565	3,050	2,490	2,790	13,205
4	12- 6 a. m.....	1,200	1,020	2,400	2,825	2,300	2,780	12,525
	6-12 a. m.....	1,155	980	2,420	2,625	2,100	2,760	12,040
	12- 6 p. m	1,090	940	2,360	2,400	1,900	2,720	11,410
	6-12 p. m	1,045	900	2,295	2,200	1,725	2,620	10,785
5	12- 6 a. m.....	1,000	860	2,220	2,000	1,500	2,530	10,110
	6-12 a. m.....	960	810	2,150	1,775	1,350	2,370	9,415
	12- 6 p. m	905	760	2,085	1,600	1,245	2,250	8,845
	6-12 p. m	845	710	2,015	1,440	1,150	2,120	8,280
6	12- 6 a. m	800	660	1,940	1,330	1,080	1,980	7,750
	6-12 a. m	750	610	1,870	1,240	1,000	1,810	7,280
	12- 6 p. m ...	700	520	1,805	1,200	940	1,700	6,865
	6-12 p. m	650	490	1,740	1,140	800	1,650	6,470
7	12- 6 a. m.....	600	440	1,670	1,100	800	1,600	6,210
	6-12 a. m ...	550	390	1,605	1,080	760	1,650	6,035
	12- 6 p. m	500	340	1,535	1,005	750	1,600	5,730
	6-12 p. m	450	300	1,465	1,055	785	1,620	5,675
8	12- 6 a. m	400	260	1,400	1,050	780	1,660	5,550
	6-12 a. m.....	350	210	1,335	1,050	811	1,700	5,456
	12- 6 p. m ...	300	160	1,265	1,080	920	1,750	5,455
9	12- 6 a m.....	250	100	1,125	1,075	1,100	1,800	5,510

[a] At Chatham.

l run-off, 8,961,248,000 cubic feet.

The measurement station established upon the Upper Passaic River at the village of Stanley, near Chatham, is shown on Pl. VIII, *A*. It lies about 300 feet below the Stanley dam, which was carried away during the flood. No appreciable overflow of the banks occurred, and the results obtained by current-meter measurements are trustworthy. After the destruction of the dam the millrace carried no water, and there was therefore no necessity for taking the race discharge into account. The station established at Whippany Village, near the mouth of Whippany River (Pl. VIII, *B*), is probably the least satisfactory of the Highland stations. During the height of the flood the water left the banks of the stream and overflowed the road for a few hours. The time limits and the depth of water so overflowed were, however, accurately observed and the measurements are sufficiently trustworthy for the present purposes.

The station on the Rockaway River, about 2¼ miles below Boonton, was established on a cross section of the channel, in the center of which an island is situated, necessitating the measurement of two channels (see Pl. IX, *A*). The records obtained at this point do not include the entire flow of Rockaway drainage area, as the station is about 7 miles above the watershed limits. A large part of this area, however, is included in the wet lands described in the introduction, over which the water rose during the flood. This station, although serving fairly well in high water, is useless during dry seasons, and it has since been abandoned.

The measurements upon the Pequanac River are more trustworthy than those on any other highland tributary, because accurate gage readings were maintained by the water department of the city of Newark, at the Macopin dam during the entire flood period (see Pl. IX, *B*). This dam has been accurately rated by Mr. John R. Freeman, and the results of weir measurements can be depended upon. Additional measurements were also made with the current meter at the New York, Susquehanna and Western Railroad bridge, a few miles above the mouth of the river. The combination of the two series serve to give an approximately correct estimation of flow in the Pequanac River during the flood. In the table on page 37 the stated flow of the Pequanac River embraces only that volume of water which actually passed into the Pompton, and does not include the daily draught of 371 second-feet for the supply of the city of Newark, withdrawn at the Macopin intake.

A short distance above the mouth of the Wanaque the channel forks, and the two divisions are crossed by a highway bridge built in two sections to conform with the channels (see Pl. X, *A* and *B*). The distribution of the flow of Wanaque River into two comparatively wide channels gives shallow water even during floods, and the broken, uneven surface on the bottom renders good current-meter measurements somewhat hard to obtain.

A. MEASUREMENT STATION ON ROCKAWAY RIVER NEAR BOONTON.

B. MACOPIN DAM.

The measurement station on the Ramapo was located near the mouth of the river on a highway bridge just below Pompton Falls (Pl. VI, *A*). The channel here is deep and well defined, and the measurements given in the table are trustworthy. The flow of water in the raceway running from the head of Pompton Falls has been measured and proper allowance therefor has been made in the table.

A study of the table on page 37 will show that in each of the Highland tributaries the rise of water during the flood was rapid and the crest was not long sustained, recedence following almost as quickly as the rise. The combined flow of the tributaries must, therefore, during a short period, have been enormous, and it is readily inferred that a channel of great capacity would have been necessary in order to carry away immediately the waters delivered into the central basin. It has been stated, however, that the channel at Little Falls is a narrow one and is artificially constricted by the aqueduct of the Morris Canal, as shown in Pl. VI, *B*. The area contributing to the flow of the Highland tributaries is approximately 636.2 square miles, or 82.2 per cent of the total area above Little Falls. The run-off from the remaining 17.8 per cent could not be measured and can be estimated only by taking the proper proportion of the entire run-off of the area. Bearing this in mind, let us consider briefly the flow of water over Beattie's dam at Little Falls, a plan of which is shown in fig. 6.

FLOOD FLOW AT LITTLE FALLS.

The rating table for Beattie's dam consists of three parts, which are adjusted to conform with the conditions existing at the main dam and the north and south wings. Back of the main dam the river has been filled with stone to a considerable distance, affording a very gradual slope forward from the bottom of the stream to the crest of the dam, the grade being approximately 5 to 1. Bazin's series for wide-crested weirs was used in the flow calculations at this point, the coefficients which appeared to be most applicable being those determined in Cornell University Experiment No. 3, under the date of May 26, 1899. The north and south banks have vertical faces, the crest in each case being about 7 feet from the bottom of the stream. The series of Bazin most nearly conforming to these conditions is No. 114, developed for greater heads at Cornell University June 1, 1899, and denoted as Experiment No. 10.

Calculating the flow of water over Little Falls dam during the flood period, the results diagramatically represented in fig. 7 are secured.

Inspection of the accompanying diagram does not reveal any unusual characteristics. It is a conventional flow curve such as is usually found upon investigation of any flood. The rise of water is considerably sharper than the decline, and the height of the flood is maintained for a considerable period, arriving at an apex at noon on March 2. It will be noted that the flow curve is ended with the value for March [illegible] at 6 a. m. This is because a second rise in the waters took pla

as a result of a storm which was entirely distinct from those wh occasioned the flood under discussion. Pl. V, *A* and *B* shows clea

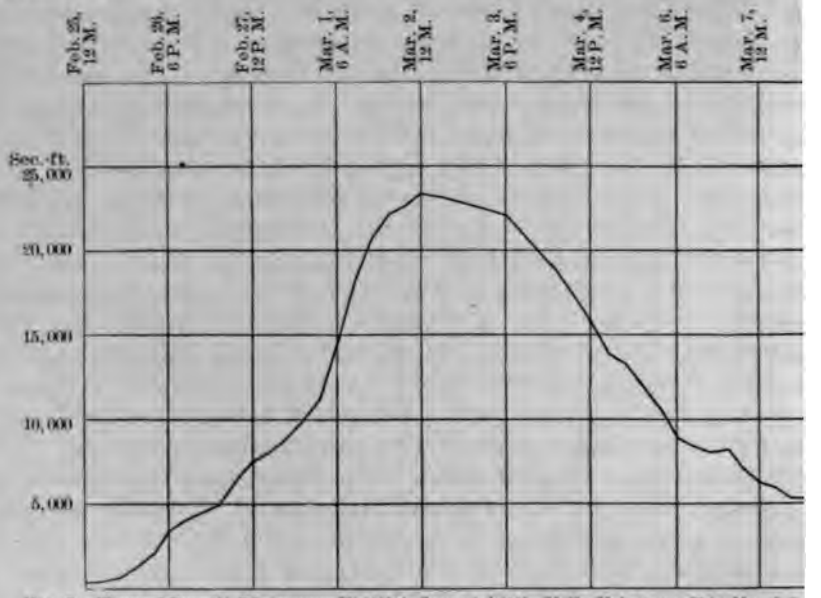


FIG. 7.—Flow of Passaic River over Beattie's dam at Little Falls February 25 to March 9,

the comparative conditions existing in the gorge during low water a at the time of the flood under consideration. It will be seen that

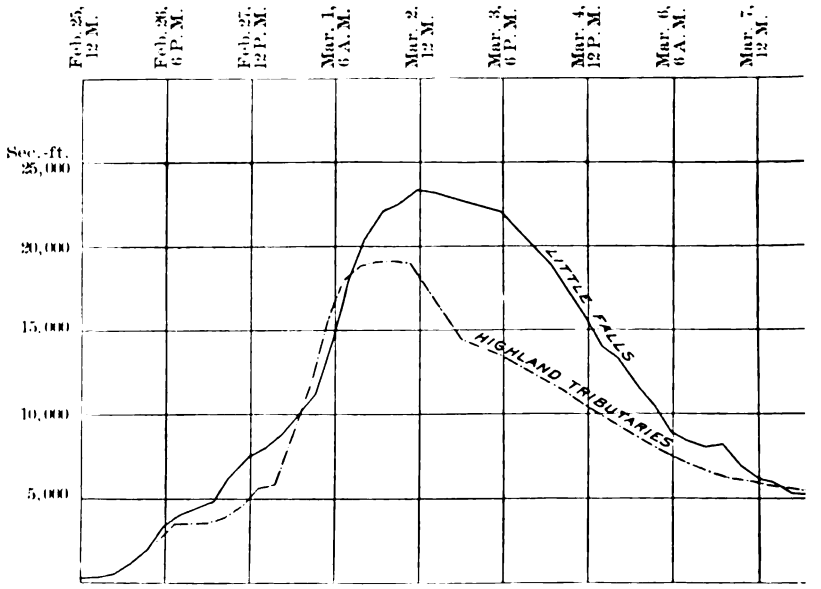


FIG. 8.—Comparative diagram of the flow from Highland tributaries into the central bas the Passaic and the flow from Beattie's dam at Little Falls.

rise here is considerably greater than over Beattie's dam, a short *tance* above, denoting a carrying capacity even less than the dam

...ving now considered the flow of water from the Highland tribu-... into the central basin through Little Falls gorge during the flood ...d, it will be instructive to compare the two flow curves and show ...elations, so far as possible, between the flow of the water into the ... on the one hand and the flow out on the other.

...spection of the table on page 37 indicates that the rush of water ... the Highland tributaries into the central basin during the crucial ... of the flood was greater than the flow of the river at Little Falls. ...s condition is indicated from 3 p. m. on February 28 to 12 m. on ...ch 1. It is clear that if, to this flow from Highland tributaries, ...dd the estimated run-off not represented in the Highland tribu-... curve, the excess of water delivered upon the central basin dur-... this short period, over that passed through the Little Falls gorge, ...ld be still greater. It is interesting to note that the excess of ... at Little Falls indicated in the diagram, during the period between ...'clock noon on March 1 and 6 o'clock p. m. on March 7 is nearly ...al to the calculated flow from the central basin, the 17.8 per cent ...he drainage area above Little Falls not represented in the High-...l tributary curve. It should also be borne in mind that in the ...tral basin the precipitation causing this flood was heavier than ...where in the surrounding country,[a] and this would in a large ...ree compensate for the excess which still appears after deducting ... calculated flow of the 17.8 per cent from the excess of the Little ...ls readings over those of the combined Highland tributaries.

...onsidering fig. 8 as it stands, however, it gives clear testimony ...t until a certain height of water was raised over the central basin, ...ucing, of course, a heavy pressure upon the outlet at Little Falls, ... gorge did not carry anything like the amount which was subse-...ntly observed to be flowing over Beattie's dam.

...NERAL FLOOD-FLOW STATISTICS IN HIGHLAND TRIBUTARIES.

...n the table below are given the general flood-flow statistics in ...hland tributaries:

General flood flow in Highland tributaries.

Measurement station.	Contributing drainage area.	Percentage of contributing area to total above Little Falls.	Total run-off for each station.	Run-off per square mile.	Run-off in inches on watershed.
	Sq. miles.		*Cubic feet.*	*Cubic feet.*	
...aic, at Chatham	99.8	12.9	825,847,200	8,275,022	3.5
...ppany, at Whippany	55.9	7.6	716,364,000	12,281,510	5.5
...away, below Boonton	125.4	16.6	1,737,841,600	13,850,411	5.9
...nac, below Bloomingdale	84.8	10.9	1,829,352,600	21,572,240	9.3
...aque, at Pompton	109.6	14.2	1,645,250,400	15,011,411	5.8
...apo, at Pompton Lake	160.7	20.8	2,205,619,200	13,725,073	5.9

[a] See table on p. 38

SUBMERGED LANDS IN CENTRAL BASIN.

Among the notable features of the flood were the effects of the rush of water into the central basin, the submerged area, 32,000 acres, being of unusual extent. It will be observed by inspection of the shaded portions of Pl. XI that the impounded waters were divided into two distinct areas. The widely extended and irregular tract embracing what is known as the Great Piece Meadow, Troy, Black and Long meadows, Hatfield Swamp, and the Bog and Vly meadows has an area of 22,746 acres, while the Great Swamp, situated farther to the south and divided from the former accumulation of water by the terminal moraine, has an area of 9,376 acres. There is little question that the flooded area shown on Pl. XI was not entirely covered at one time. The water first collected in the upper

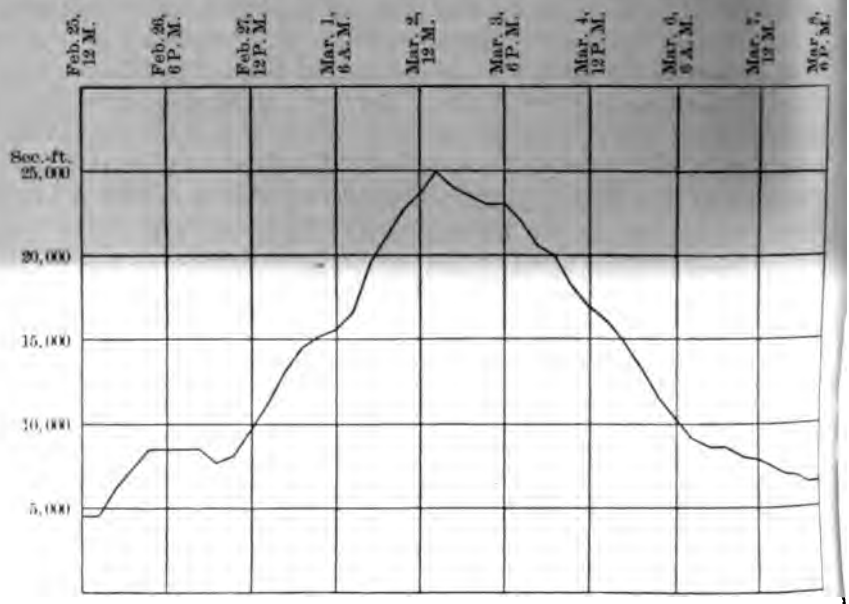


FIG. 9.—Flow of Passaic River over Dundee dam February 26 to March 9, 1902.

portions of the swamp land, and there was considerable slope toward the outlet at Little Falls. In the latter stages of the flood there was a greater area of submerged land near the outlet, while there had been a noticeable recedence above. The flooded lands will be further discussed under the section dealing with damages caused by the flood.

The point of flow measurement next below Little Falls is at Dundee dam, a diagrammatic representation of the gage heights of which was given in fig. 9. The dam has already been partly described. It extends directly across the bed of the stream, and the upper and lower faces slope from the crest. On the upper face of the dam there is a fairly uniform grade of 2–1 to the river bottom, while on the lower face the dam is built up of sixteen consecutive steps, with 1-foot

A. GAGING STATION NO. 1 ON WANAQUE RIVER AT POMPTON.

B. GAGING STATION NO. 2 ON WANAQUE RIVER AT POMPTON.

rs and 1-foot treads. This gives a slope of 1-1, but on account of deterring effect of the steps during flood flow the coefficient to pplied in determining the volume of water passing over the dam t necessarily conform to that determined for a batter of gentler e. The coefficients selected were those promulgated in Cornell versity Experiment No. 8, dated May 30, 1899, which is an adapta- of the Bazin series No. 78 for greater heads. Fig. 9 shows dia- amatically the flow over Dundee dam during the flood of 1902.

FLOOD FLOW AT DUNDEE DAM.

xamination of the above flow curve reveals that there are pecul- ies in the rise of the flood not noted in the flow curve for Beat- dam, namely, two decided checks in the progress of the flood. m the examination of similar curves for previous floods over this

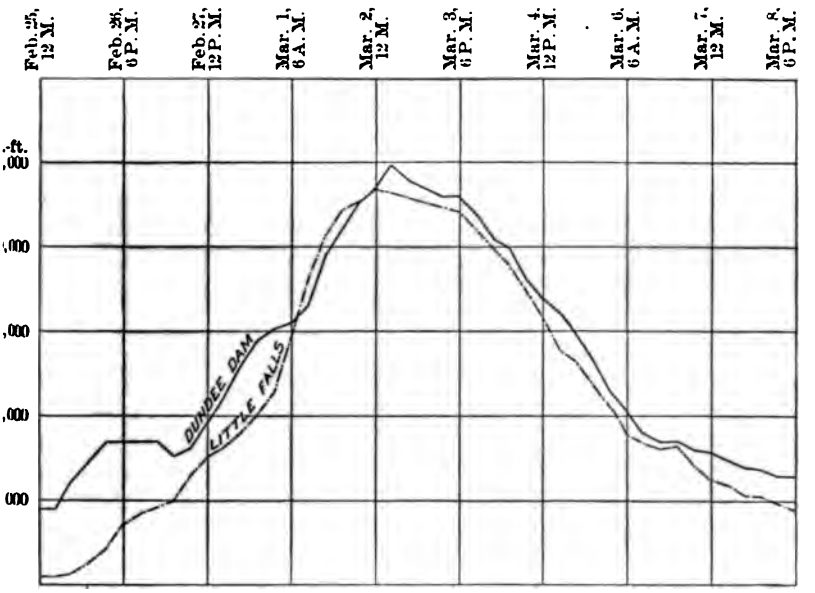


FIG. 10.—Flood flow curves over Beattie's and Dundee dams showing relations.

ı, checks of this nature appear to be a characteristic feature, the se of which has not been definitely determined. It has been sug- ed that the decrease in the flow in former floods has been caused the onrush of water from Pompton River which, as has been lained, flows into the central basin with the combined discharge he Ramapo, Wanaque, and Pequanac rivers from steep grades, s delivering its waters before those of the more sluggish Passaic descend its sinuous course, and that when the force of the flood he Pompton expends itself there is a temporary check in the prog- of the rise of waters below. However true this may be in the of other floods, it certainly does not apply in this instance. re is no evidence from the examination of the flow curve at Little *s that any such phenomenon* occurred, and what is more convinc-

ing, the check took place nearly two days before the flow from the Pompton River had reached its maximum. It is extremely probable that these peculiarities in the rise of the flood are the result of the run-off from the area between Little Falls and Dundee dam. It is naturally a quick-spilling area, having been divested of forests and containing a comparatively large expanse of macadamized roads and paved streets. The large city of Paterson and the surrounding area empties its entire run-off into the Passaic, and this in itself would have some effect upon the rate of increase after great precipitation.

Comparison of the flow curves in fig. 10 seems to support the contention advanced concerning the cause of the temporary checks in the progress of the flood curve over Dundee dam. It is expected that the increase in the flow over Little Falls dam would be a practically constant one because of the steadying effect of the great storage afforded by the meadow lands, and the steady rise in the Little Falls curve bears out this idea. The Dundee curve, on the other hand, shows at the beginning every indication of a flashy, quick-spilling contributing area, the effects of which are not overcome until the flood has advanced to within one day of its maximum. At that time the steady pressure from Little Falls seems to give more character to the Dundee curve, and the remainder of the diagram is conventional. It will be noted that the apex of the Little Falls curve falls twelve hours before that of Dundee dam, which is about the time which might be expected to ensue when we consider the comparatively large storage capacity afforded by Dundee Lake.

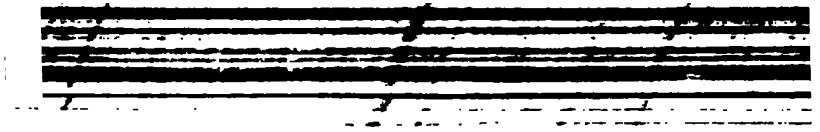
FLOOD BELOW DUNDEE DAM.

The action of the flood waters below Dundee dam was sufficiently different from those in the valley above this point to warrant special mention.

The physical character of the valley from the dam to the mouth of the river is strikingly different from that of its other sections. As has been stated, it consists of, first, a short reach of 4 miles through the city of Passaic, with a total drop of 6 feet. At this point the river turns sharply and returns to its former direction in a broad S-shaped bend. This peculiar bend is significant in connection with the supposed change of the stream's course during Glacial time. It also has a bearing on flood conditions in that it lies in a flat basin-like widening of the valley, and high waters, especially such as come with much force, are forced to leave the channel and invade the surrounding low-lying territory. The second distinguishing feature is that below this point the river becomes a tidal estuary 13½ miles in length, and lies in a constricted valley which becomes narrower as the mouth of the river is approached. At Passaic, Belleville, and Newark docks have been constructed, which still further decrease the natural width of the channel, and in addition to them a number of railway and

A. DAM ON PEQUANAC RIVER NEAR POMPTON.

B. SUBMERGED FLAT LANDS AT SINGAC.



ghway bridges have been built across the stream, which by piers d abutments more or less obstruct the flow.

In this section of the valley population is dense, and with the single ception of the low-lying portion of the city of Paterson manufacring and other interests are more seriously affected by high water an elsewhere upon the watershed.

The waters of the lower river fairly followed the gage heights at ndee dam during the first part of the flood. On February 27 the ters were high; on the 28th they had arisen above the right bank Passaic bridge and flooded the highway at this point. On March 1 e flats situated above Wallington and the areas adjacent to the er on both sides for several miles below were flooded. On this and e following day water rose above the floors of the highway bridges Passaic, Rutherford, Avendale, and Belleville, and these bridges re in great danger of being carried away, while the bridge at Pasic, just below Dundee dam, was lifted from its foundations and mpletely wrecked (Pl. XV, *B*.) This danger was much increased by e amount of débris, especially in the form of driftwood from lumber rds, which became lodged against the piers and bridge spans. The ie Railroad bridge at Passaic was threatened and trainloads of avy iron and coal were placed upon it to add to its stability. On arch 3 and the days following the waters gradually subsided until e normal stage was resumed.

FLOOD FLOW OF SADDLE RIVER.

In connection with the flood in the lower valley should be consided the discharge of the Saddle River, which enters the Passaic just posite the city of that name. Although this stream joins the main ink below the dam at Dundee, where one of the main flow computions was made, and though its volume was not included in the scharge curves given above, it still seemed to have an influence in elling the volume of the waters near Passaic and Wallington and creasing the damage done at these points.

From evidence secured at Boetger Piece Dye Works at Lodi, the ddle River began to rise on Friday, February 28, at about 6 p. m. It se steadily until Saturday morning, March 1, between 2 and 3 o'clock, maining high until 7 a. m. of the same day. By 5 o'clock p. m. on turday, March 1, the waters had receded within their banks, and adually declined in volume for the next five or six days.

No measurement was made of its flood discharge, but on April 12, 02, a current-meter measurement showed 221 second-feet flowing at di, the water at the time of the flood being 7.6 feet higher than at e time of the measurement.

The flood on this river closely resembled previous floods in rising and iring quickly, and the crest of its flood wave reached the main stream fore the waters from the other tributaries entered the lower valley. Although the flood crest of Saddle River did not play an important

part in the flood on the main stream, its subsequent discharge, mu larger than usual, coming in conjunction with the rising waters of t main stream, must have had its effect in increasing the damage in t Wallington-Passaic district.

At Passaic Bridge near the southern extremity of the flat extensi of the valley just mentioned the main line of the Erie railroad cros the flats on an elevated embankment and passes over the river o drawbridge. This bridge has two piers in the river, as shown on I, *A*. Each of these piers is surrounded by piling which in times high water catches much floating débris and acts as a tempor obstruction to the current. The distance from the abutment on right bank to the main pier, that which supports the draw, is 209 f and from the main pier to the abutment on the left bank, 81.5 fe West of the main abutment, as seen on the left of Pl. I, *A*, a hi way passes beneath the elevated tracks through a masonry culvert feet wide at the base. The entire discharge from the watershed of o a thousand square miles is obliged to pass through these openin which have a total width of 350.5 feet, and which in very high wa are more or less contracted by the lodgment of débris against piers. During the flood under discussion the water rose over the ro way shown on the left of Pl. I, *A*, and stood for some time above level of the stone walls seen on the extreme left. The high-wa mark on the bridge itself was about half way up on the middle dr of the draw plainly seen above the piling in the picture.

HIGH-WATER MARKS IN LOWER VALLEY.

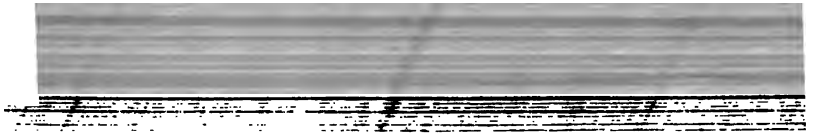
By the courtesy of Mr. Robert M. Watson, of Wise & Watson, en neers, of Passaic, N. J., we are permitted to use the following lev taken at the time of high water at different points from Passaic Belleville:

High-water marks in lower valley.

[Elevations given are reduced to the State's datum.]	Elevat in fe
At Enameline's Works, southerly corner of Seventh and Worthen streets (Dundee district), in city of Passaic, near right bank Passaic River	15
In engine room Passaic Lumber Company's mill, northerly corner Lester and Scott streets, in borough of Wallington, Bergen County, N. J	15
On northwesterly fence Standard Bleachery property, at a point about 200 feet northeast of Erie Railroad at Carlton Hill, Bergen County, N. J	15
On office building of Anderson Lumber Company, on right bank Passaic River, near foot of Gregory avenue, in the city of Passaic (and on River Road)	14
On entrance to Pagoda Hotel, near right bank of Passaic River on River Road, and about 150 feet southwest of Erie Railroad bridge across Passaic River, in the city of Passaic	13
On northwesterly corner piazza E. T. Galloway's house, at easterly corner River Road and Woodward avenue, in the borough of Rutherford, Bergen County, N. J	12
On Powell's front stoop, south side of Rutherford avenue, about 500 feet southeast of Passaic River	11

A. FLOODED AREA ON GREAT PIERCE MEADOWS.

B. FLOOD AT TWO BRIDGES.



	Elevation in feet.
ınd at carriage entrance to William R. Traviss's estate, on Valley avenue, near southerly corner Valley Brook and Park avenues and Road, at Lyndhurst, Bergen County, N. J	11.00
hree inches higher than wheel guard on Avondale bridge across .c River, between Essex and Bergen counties	10.31
esterly pier Belleville bridge across Passaic River, between Essex ergen counties	9.21

ı these a profile of the flood ıas been drawn and is also ɔd (fig. 11). In the profile the base line represents the ordiıean water level of this part river, while the flood crest is ɔnted by the irregular line at each point where levels ıken profiles of cross sections valley have been inserted to ;he extent to which waters wed the banks.

riking feature, not brought ' this diagram, is found in tion with the levels at the ırd Bleachery and at Passaic , just above and below the ailroad bridge. The Standıachery is located on the north ' the Erie Railway embank- (about one-third of a mile 'rom the stream at Passaic), and at the eastern edge flat area on the left bank river on which also stands ırough of Wallington. The ery level was 15.98 feet, while ı the north side of the bridge out 14.65 feet, as taken from ł levels a few days after ıters had subsided. It has uggested that the high level Standard Bleachery, which to be well authenticated, ave been due to the onrush waters of the main stream ɔr with the heavy discharge dle River, which forced the over the Wallington flats mporarily piled it up against the obstructed embankment and ng land near which the Bleachery is situated.

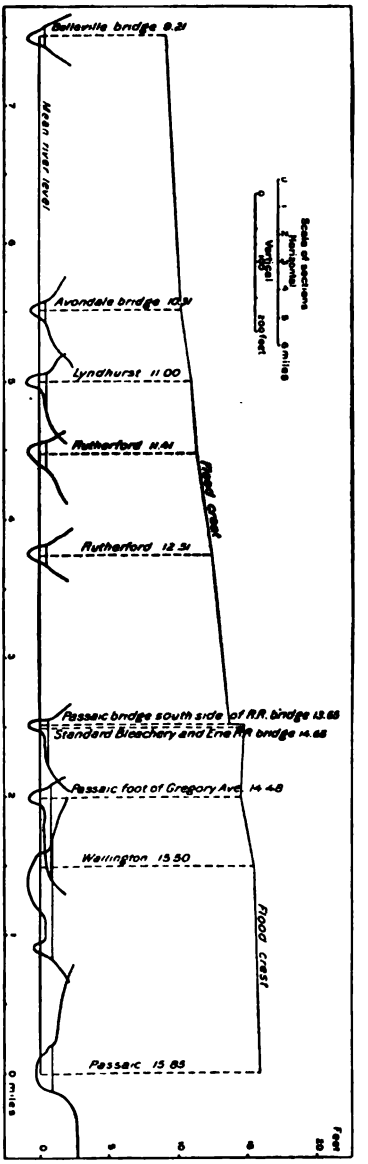


Fig. 11.—Profile of flood crest, Passaic to Belleville.

The next level was taken at Passaic Bridge, but a few feet the Erie bridge and embankment. This level was recorded a feet, a difference between that on the north side of the bri about 1 foot (see fig. 11). Eyewitnesses on the ground at the t the flood testified that there was a striking difference in the he the water on the north and south sides of the Erie abutmen that the water poured between them as over a sloping bed.

The various section profiles of the valley accompanying fig. 1 again the gradual narrowing of the valley which was before r to in the general discussion of the river, and was there att to the possible change of drainage which has taken place geologic times.

LOSSES CAUSED BY THE FLOOD.

Floods of such magnitude as the one under discussion r necessity cause great damage, but from the varying nature losses and the circumstances surrounding them it is impos make more than an approximation of their amount.

As might be expected, the losses were greater in the centra and lower valley than on the tributaries in the Highland ar the last-named section, the proportion of population being sma few industries centering upon the rivers, there was little oppo for extensive damage. The valleys are so narrow and stee that there was comparatively little flooding of highways and floors. One or two dams were carried away, notably that at P on the Pequanac (Pl. XII, *A*), and some of the highways mountain valleys were flooded.

In the central basin the losses were much greater, being occa by extensive flooding of farm lands (see Pl. XIV, *A* and *B*) ing considerable damage to stock and personal property. In instances cattle and horses had to be removed to places of and suffered much from exposure. Barns, cellars, and hous flooded (see Pls. XII, *B*, and XIII, *B*) and the inmates were c by the waters. The damage was furthermore much exagger the unusual duration of the flood, the waters remaining on lands of the basin for more than a week.

Three railroad lines cross this portion of the Passaic wate the Morris and Essex and Boonton branches of the Delaware awanna and Western Railroad and the Greenwood Lake Br the Erie Railroad. The first two lines traverse the basin for t part at altitudes higher than the level of the flooded area; l Greenwood Lake Branch runs for several miles over a section flat lands and was much affected by the flood conditions. The of this road were flooded above Singac, also at Mountainvi below Pompton Plains. The water reached the ties of its across the Passaic at Signac and the structure was only held i

A. FLOODED FARMHOUSE IN CENTRAL BASIN.

B. FLOODED FARM LANDS IN CENTRAL BASIN.

y trains heavily loaded with iron and coal. Just above this point ie track was washed over by the overflow from the left bank of the ver and large portions of its gravel embankment were carried away. ortunately there are no large towns located in the flooded lands of ie upper basin, or the damage to individual property holders would ave been much more serious.

In addition to the injury to private property the chief damage in is part of the drainage area consisted in that sustained by the ridges from débris and floating ice, the complete suspension of travel y the flooding of highways, and the loss and inconvenience due to ie interruption of travel upon the railroad lines.

Some of the highways were passable with difficulty, but many of hose most used, especially such as run near the main stream, were rossed in many places by swift currents of water from 3 to 6 feet in epth, through which passage was impossible except for the most eavily loaded wagons.

The total area of the flooded lands, as seen by reference to the map f the central basin, Pl. XI and various plates of the report, was pproximately 32,000 acres. A number of dams were carried away n the tributaries near the edges of the central basin, notably that n the Passaic proper at Stanley. Fortunately the water confined by hese structures was not enough in amount to seriously damage the ower portions of the valley below Little Falls, and from that point to he mouth of the river the damage was of a different character.

As has been described, the valley below Little Falls is comparavely narrow and thickly populated, Paterson, Passaic, and the intervening towns being closely built up to its banks. Between Paterson nd Little Falls the roads on both sides of the stream were flooded, and he trolley line—much used by employees of factories at Little Falls vho reside at Paterson and depend upon the line for transportation—vas completely blocked for several days. The pumping station of the East Jersey Water Company, located at the foot of the main drop at Little Falls, was considerably damaged by the rise of waters, which looded its main floor to a depth of several feet, stopping all operations and injuring the pumps and electric motors which were there nstalled. Pl. VI, *B*, shows the water standing at a higher level than he floor of the pumping station as seen looking downstream under he viaduct of the Morris Canal.

Below the main falls in Paterson the city closely confines the river n both banks. The left bank stretches back some distance from the tream as a low bench, which is built up with residences. This section was flooded for several blocks and remained under water a number of days. Many houses were damaged by the water, and while he individual losses were not heavy, they still amounted to considrable in the aggregate. On the right bank of the river the section xtending several blocks east of River street was under water. This

SUMMARY.

From the foregoing discussion it is seen that the Passaic River is of importance, both on account of the large manufacturing interests which depend upon it to a certain extent for power, and on account of the cities which use it as a source of municipal water supply.

The Passaic drainage basin is peculiar in respect to its physical features. Unlike the ordinary habit of river systems, in which the tributaries join the main trunk at intervals on either side, resembling the veins of a leaf, the important tributaries of the Passaic deliver their waters to the main stream at points not far from the middle of its course. They, moreover, flow from a mountainous region with rapid fall, and meet the main artery in a flat, basin-like area which easily becomes flooded at even ordinarily high stages of the stream. It has been seen that the outlet to this basin is a narrow gorge at Little Falls, restricted at its lower end by a masonry viaduct, and that in times of very high water the gorge is too small to accomodate the discharge of the river, and extensive flooding of the basin above results. It has been observed that the low-lying portions of Paterson, Passaic, and the neighboring towns on the banks of the river in its lower course are subject to overflow during high freshets, which damage not only individual householders, but also the large manufacturing interests there located. The striking physical relations of the lower valley have also been touched upon, namely, that there is a gradual narrowing of the valley as the mouth is approached, which seems to have congested the outlet of flood waters in this portion of the drainage area.

With regard to the conditions preceding and accompanying the flood of 1902, it has been observed that during the latter part of February of that year approximately 6 inches of precipitation, composed of melted snow, sleet, and rain, were released upon the frozen drainage area, and that much of this water passed rapidly into the streams.

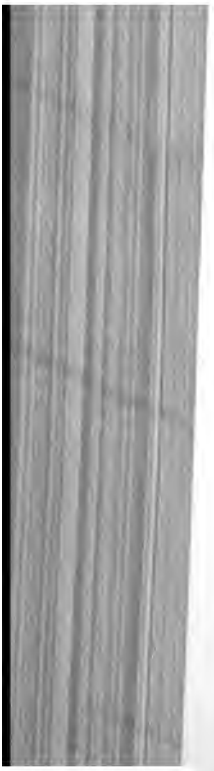
It was also seen that the mountain tributaries discharged large volumes into the central basin, flooding approximately 32,000 acres of its area and doing considerable damage to farming and railroad interests there located.

As indicated from gage heights, the rise of water began at Dundee dam about 6 p. m. on February 25, and, after subsiding slightly on February 26 and 28, reached its maximum of approximately 24,800 second-feet on March 2. The flow curve of the flood over Little Falls dam was quite similar to that at Dundee dam, the apex of the former occurring a few hours before that of the latter.

In regard to the damage done by the flood, the most general estimates only can be made, but in Passaic and vicinity, the section which probably suffered most severely, $1,000,000 is thought to be a small approximation of the losses sustained.

A. WALLINGTON DURING FLOOD.

B. FAILURE OF BRIDGE AT PASSAIC.



d Paterson, with the exception of the city of Newark, no great mage was done, though much inconvenience and several cases of were personal loss resulted.

It is estimated that the value of the bridges which were swept away the flood (Pl. XV, *B*) in various portions of the watershed mounts to not less than $300,000, in addition to the losses noted ove.

COMPARISON WITH PREVIOUS FLOODS.

It will be of interest to compare the flood of 1902 in the Passaic alley with those of other years. Previous to 1902 the greatest flood the Passaic River for a century, at least, occurred in September, 82. Mr. C. C. Vermeule, in the Report of the Geological Survey of ew Jersey, Vol. IV, reports concerning this flood as follows:

The flood of 1882 was probably the highest of this century, consequently more ood marks are preserved and a better recollection prevails of this than of other oods. By inquiry and comparison of data of other floods which I have obtained have been able to construct a fairly accurate history of this flood. The waters egan to rise at Dundee and Little Falls in the afternoon of the 22d, and rose teadily for 33 hours, when they reached 16,049 cubic feet per second. They then ell off for about 10 hours to 13,000 cubic feet per second, and then rose until they eached a maximum 66 hours after the beginning of the rise of 18,265 cubic feet er second at Dundee and 19,100 cubic feet at Little Falls. The upper branches ppear to have discharged their flood waters into the central valley within 72 ours, and to have subsided within their banks. They reached their maximum ischarge in from 20 to 40 hours after the beginning of the rise on the Passaic. n the following tables the maximum flows are obtained from well-defined flood arks at dams. The total discharge is estimated to be 3.13 inches on the shed, already determined.

Below are appended the leading facts regarding the flood of 1902, nd also regarding previous recorded floods, which will serve as an teresting basis of comparison.

Comparative statements concerning Passaic floods, measured at Dundee dam.

[Drainage area, 822.7 square miles.]

Date of flood.	Duration of flood.	Duration of rise.	Maximum flow.	Duration of fall.	Run-off: Inches on drainage area.
	Days.	*Days.*	*Sec.-feet.*	*Days.*	*Inches.*
ebruary 25 to March 9, 1902	[a] 12	5.00	[a] 24,800	[a] 7.00	7.1
eptember 25, 1882 [b]	8	2.75	18,265	5.25	3.71
ecember 12, 1878 [b]	8	2.50	16,592	5.50	3.47
ebruary 14, 1886 [b]	8	2.50	12,452	5.50	3.00
anuary 3, 1888 [b]	8	2.80	11,880	5.20	2.77
anuary 24, 1891 [b]	8	2.50	11,701	5.50	2.56
arch 14, 1893 [b]	9	2.90	11,245	6.10	3.56
ay 6, 1893 [b]	8	3.00	11,155	5.00	2.77
eptember 21, 1888 [b]	8	2.75	11,126	5.25	2.89

[a] Estimated. [b] From Report of New Jersey Geological Survey, Part III, 1894.

Page.
Pompton, gaging stations at, views of ... 42
Pequanac River at, flow of ... 27
Ramapo River at, fall of ... 15
Wanaque River at, flow of ... 27
Pompton Furnace, height of water at ... 35
Pompton Lake, falls at ... 24
Pompton Plains, Pompton River at, flow of ... 27
Pompton River, drainage area, length, fall, and gradient of ... 19
flow of ... 20, 22, 24, 26, 27, 29
Precipitation. *See* Rainfall.
Rainfall in Passaic Valley ... 31-34
Ramapo River, course and character of ... 15-16
drainage area, length, fall, and gradient of ... 19
flood flow of ... 37, 41
flow of ... 27
height of water in ... 35
profile of ... 18
Ringwood, rainfall at ... 32, 33
Rivervale, rainfall at ... 32, 33
Rockaway River, course and character of ... 17
drainage area, length, fall, and gradient of ... 19
flood flow of ... 37, 41
flow of ... 27
measurement station on, view of ... 38
profile of ... 18
rise of ... 34
view of ... 30
Roseland, rainfall at ... 32, 33
Rutherford, high-water mark at ... 46
Saddle River, course and character of ... 15
drainage area, length, fall, and gradient of ... 19
Saddle River, flood flow of ...
profile of ...
Sherred, M. R., acknowledgments to
Singac, submerged flat lands at, view
South Orange, rainfall at ...
Stanley, measurement station at, view
Passaic River at, flow of ...
Two Bridges, flood at, view of ...
Passaic River at, flow of ... 21, 2
Pompton River at, flow of ... 20, 2
Vermeule, C. C., acknowledgments to
quoted on flood of 1882 ...
reference to ...
Wallington, flood at, view of ...
high-water mark at ...
losses at ...
Wanaque River, course and character
drainage area, length, fall, and dient of ...
flood flow of ...
flow of ...
gaging stations on, views of ...
Watson, R. M., acknowledgments to
aid by ...
Water, height of ...
Wet lands, area of ...
Whippany, measurement station at,
of ...
Whippany River at, flow of ...
Whippany River, course and chara of ...
drainage area, length, fall, and dient of ...
flood flow of ...
flow of ...
measurement station on, view of
profile of ...

O

Po

Po
Po
Po

Po

Pr
Ra
Ra

Rin
Riv
Ro

Ros
Rut
Sad

Stanford University Libraries
3 6105 007 631 158

To avoid fine, this book should be returned on
or before the date last stamped below

25M—7-42

659123